

Talking Movies

James R. Cameron

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E. LUDWIG NEUSS



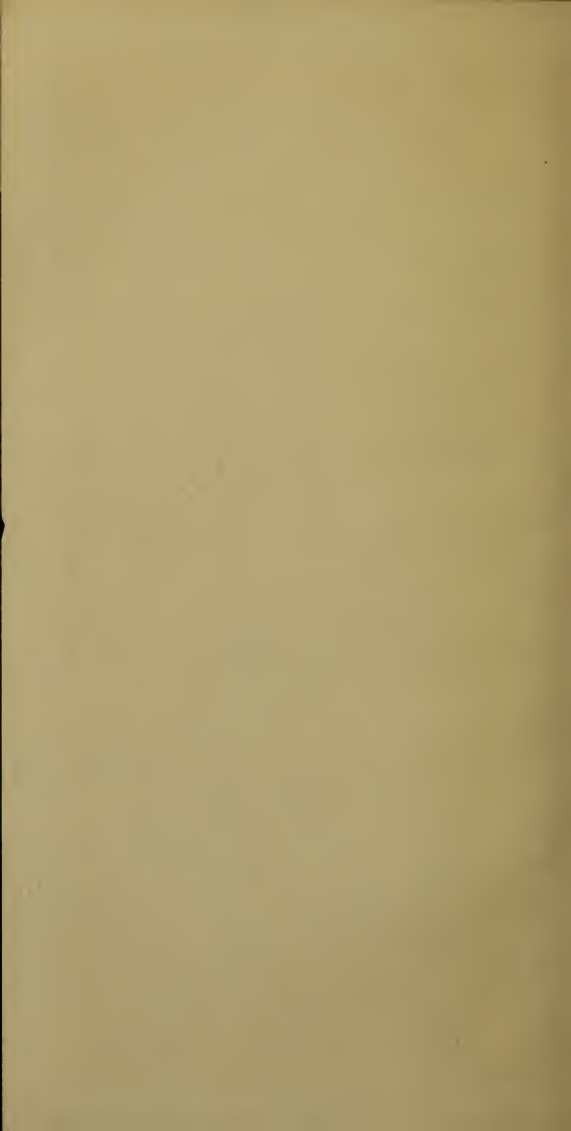
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Talking Movies

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Talking Movies



By James R. Cameron

Author of

Motion Picture Projection — Electricity for Operators — Motor and Motor Generators — Pocket Reference Book for Managers and Operators — The Taking and Showing of Motion Pictures for the Amateur, etc., etc.

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THE AMERICAN CINEMATOGRAPHER

MR. LEE DE FORREST, the

SOCIETY OF MOTION PICTURE

ENGINEERS

*and all others who in any way
assisted me with this work.*

New York City, 1927


J. R. C.

To the "old timer" in the motion picture business the statement that talking movies are by no means a product of yesterday is no news. In the patent office in London, England, the first patent for the taking and showing of motion pictures synchronized with sound dates back to the year 1892. Between that year and 1912, no less than 91 patents were granted on apparatus dealing with either the taking or showing of motion pictures with sound. In this country we all remember Edison's Phonograph and Kinetophone in the early days of motion pictures. Up until three or four years ago talking movies seemed a dead issue then along came De Forest with his Phono Film, the Warner Bros. With the Vitaphone, Fox Film Corp, with the Movietone, and the General Electric Co. with their systems, and the whole subject is revived again.

In this work the writer has divided the subject into two parts the first is a history of the talking movie from the year 1900 up to the outbreak of the world war, and for this part of the work the writer is indebted to Messrs. Honwood and Foster, the second part deals with the various systems now being used with success in the theatres of this country.

J. R. C.

New York City.

O make a picture on the screen realistic something more is necessary than the visual effect alone. To see persons in the act of talking without hearing what is said, or to see waves dashing on rocks, or lions seemingly roaring away, without hearing anything other than the faint buzz of the projector, leaves an impression of something lacking. From the very earliest times this want has been felt, and it is now rarely that a motion picture exhibition is given without a musical accompaniment of some sort. A suitable and appropriate selection of pianoforte music greatly improves an exhibition, and, on the other hand, an inappropriate selection, or a bad rendering of a good selection, is worse than no music at all. An ordinary piano is all that is used in many places, but a piano, organ, orchestra or orchestra substitute, however excellent the instrument may be, have limitations; and while these can be adopted to give music harmonizing to a large extent with most pictures, there are many sounds and noises, musical and otherwise, which require special devices for imitation, such, for example, as traffic, the buzz of aeroplanes, pistol shots, waves and many others. Invention and ingenuity have not failed to supply means for imitating these in a very realistic manner, but it requires a very considerable amount of skill and practice to utilize such means to the best advantage.

The reproduction of the actual sounds, as well as the picture, was attempted in the earliest days of the movie, and was used by Demeny for his Photophone, and by Edison for his Phonokinetograph and Kinetophone. The pro-

duction of imitation sounds or effects is quite a different problem to the reproduction of the actual sounds themselves. In the latter case the sound record has to be made and reproduced with the picture. It must, moreover, keep in time with the picture; that is to say, there must be "synchronism" between the sound and the picture records. The ordinary victrola record is obtained by the action of a vibrating membrane which produces a series of indentations in a soft surface of wax. These indentations are used to reproduce the vibrations of a membrane, and thereby reproduce the original sounds. Stripped of all refinements, this is the essential principle of the gramophone. If, then, a record of the sounds can be made simultaneously with the photographic record, it would not at first sight appear to be difficult to reproduce them in synchronism. The first of these problems is rendered difficult by reason of the limitations of the sensitiveness of the recording gramophone. The recording instrument must be within a certain range of the sounds, and for a speaker or actor the range is not a large one, and it is difficult to get the instrument near enough and keep it outside the picture view. Accordingly another method has been resorted to, which is applicable in a large number of cases. The music record is taken first, and the picture film is produced to the accompaniment of the record. To succeed with this method it is obviously essential that the speaking, singing or acting, should synchronize with the sound record for synchronism between the same return and the picture film to be possible. A further limitation arises from the size of record obtainable. A small or short record means a short film. The size and length of an

ordinary record is very limited, and for a speech, sketch or piece of any material length, several records are necessary, and these would need to follow on at the proper time. Having obtained the record and picture film, the problem of reproducing them synchronously is still a formidable one. It is, of course, theoretically possible for the operator to keep his eye on the screen and his ear on the gramophone, and to control the projector or gramophone so as to maintain synchronism. This, however, throws an additional responsibility on the already overburdened operator, and is not a practicable method. Accordingly, either an auxiliary device is necessary to automatically indicate to the operator if the synchronism is being maintained, or some means by which the running of the projector or gramophone, or both, is automatically adjusted to maintain synchronism.

In one of Gaumont's earliest methods, introduced in 1902, a motor was used to drive the projector. This motor was electrically controlled from the gramophone. The gramophone drives a shaft, carrying collector rings, of an electric circuit; and carrying also rotating brushes, which rub on a divided collector, the sections of which are connected to the stator of the motor. The next step in advance is the use of synchronized motors for driving both the gramophone and the projector. Messter, in Germany, appeared to have been working on the same lines, and special types of motors were used. The two motors of identical design and the same power were driven from the same current, and in order to better maintain synchronism the motor armatures each had a number of sections which were

connected in pairs. A switchboard near the projector included a starting switch, whereby the gramophone was first set in motion; and when the record commences, the gramophone disc operates a switch to start the projector. A voltmeter on the switchboard indicated any want of synchronism which was corrected by accelerating or retarding the projector. This is effected by coupling the projector with its driving motor through a differential gearing, which was operated from a separate motor. This latter motor was started by an auxiliary two-way switch, so that the differential could be used to retard or accelerate the projector to restore the synchronism. The results obtained with the Chronophone were extremely satisfactory, and by the use of the Auxetophone, in which the sound was intensified by means of compressed air, the possibility of the Chronophone in large halls was looked upon as a possibility, as was evidenced by its use at the old Hippodrome in Paris, which had a seating capacity of over four thousand.

The use of indicators for automatically indicating to the operator any want of synchronism has been adopted by many inventors in various ways. In one of the earliest, two indicating elements were used, one consisting of a disc, rotated directly from the projector and the other a concentric pointer, rotated by an electro-magnet, which is intermittently energized by a circuit, completed on every revolution of the gramophone spindle by means of a cam on the spindle. The disc carries a mark, and so long as the mark on the disc and the pointer are coincident, synchronism is being maintained. If the pointer leads or lags, the projector is speeded up or slowed down ac-

cordingly to restore synchronism.

There is undoubtedly a comparative simplicity in such a method as this, of which there have been many varieties. In one by Thomasin, a pointer is rotated intermittently by a pawl and an electro-magnet energized from the shaft of the gramophone. The electrical escapement is mounted on a coaxial disc which is rotated in the opposite direction from the projector shaft. So long as synchronism is maintained there will be no movement of the pointer, and any movement of the pointer indicates the adjustment necessary for the projector. With this apparatus there is a single indicating element only.

Another apparatus of this type was the Vivaphone, devised by Mr. Hepworth, in London. In this instrument a wheel, B, Fig. 1, carrying the indicating pointer M, is rotated by two pawls, D, I, which are actuated by two electro-magnets, G, L. These electro-magnets are intermittently energized from the projector and gramophone respectively. The spindle B¹ of the wheel B rests between parallel bars, A³, and if synchronism is upset, one pawl will rotate the wheel more quickly than the other one, and thereby cause the pointer M to move to one side or the other. The pointer carries two red and green discs, M¹, M², which are thus brought opposite the lamp, and indicate any disturbance of synchronism. The attractiveness of the Vivaphone is that it is adaptable for any gramophone and any projector. The make and break contacts for intermittently energizing the electro-magnets are carried on two fittings, S, T, Figs. 2, 3. The fitting S rests on the disc of the gramophone, and has a knife-edge engaging in the slot of

the centre pin, and the fitting T is carried by the driving shaft of the projector respectively. These fittings, S, T, and a battery, V, are connected up with the lamp K and electro-magnets G, L, of the indicator, as shown in Fig. 4.

Another somewhat different method and apparatus, invented by Mr. Jeapes, which bears the stamp of extreme simplicity, was brought out as the Cinephone by the Warwick Trading Company. In this method a rotating pointer is attached to the gramophone and driven by it. The gramophone is positioned so that a record of the rotation of the pointer is produced on the film at one corner thereof. The gramophone is placed near the corner 10^a of the projection screen, on which the reproduction of the pointer appears. The operator then controls the projector so that the reproduction maintains the same angular speed as the pointer.

A difficulty with several synchronizing devices where an indicating pointer is used arises when a film breaks or is damaged, and a section of it has to be cut away. In such cases it is necessary to slow down the projector until the gramophone catches up, but there is no visible indication when synchronism is restored. With the Cinephone, however, the restoration of synchronism is indicated by the reproduction of the pointer on the screen.

In another type of device, by Count Proszynski, the projector is coupled with the gramophone by connecting a spindle of the projector with an air-pump, the air outlet of which is regulated from the phonograph in such a manner that when synchronism is faulty the bellows actuate a brake or otherwise control the speed of the projector.

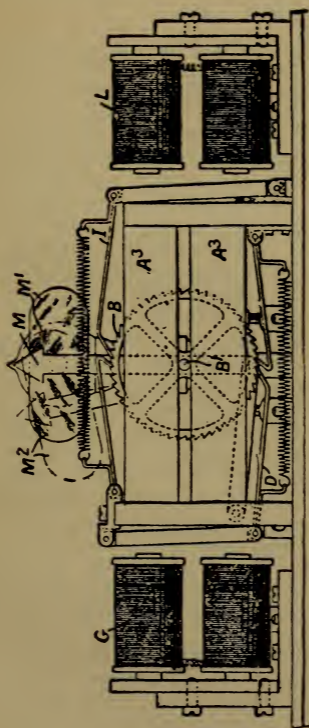


Fig. 1

In another and altogether different system, invented by Mr. Lauste in 1906, the sound as well as the picture are simultaneously recorded on the film.

In Lauste's method the sound record is made photographically. A microphone transmitter, such as is used for collecting the sound-waves at concert halls for transmission, or, alternatively, one or more horns or trumpets, *a*, Fig. 5, connecting with any ordinary loud-sounding telephone or microphone transmitter, *b*, receives the sounds, and transmits them over an electric circuit, *c*, *d*, to the receiver in the camera, A. At the receiver is an electro-magnet, B, and the varying electric currents produced by the action of the sound-waves in the microphone transmitter *b* vibrate a slotted diaphragm which moves between a fixed light and a fixed slotted diaphragm. The vibrations of the diaphragm corresponding to the sound-waves produce variations in the light openings through the diaphragms and consequently variations in the intensity of light falling on the sensitive film *m* behind the diaphragm are produced. The sensitive strip on which the light falls, is adjacent to the picture area of the film and, when developed, forms the sound record. The sound record must be made while the film is moving continuously, before or after it is fed intermittently through the gate T of the camera. It will thus be seen that the sound record on the film is a few picture lengths behind the corresponding section of the picture record. To reproduce the sound record, use is made of the fact that the resistance or conductivity of a selenium cell, when included in an electric circuit, *b*, varies in accordance with the intensity of light acting

Fig. 2

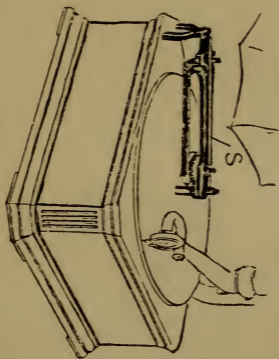
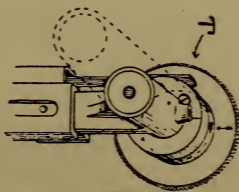


Fig. 3



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on it. In the projector, Fig. 6, the film passes between a lamp, p' , and a selenium cell, r , in circuit with a loud-sounding microphone or telephone, H . The variations in the current produced by the variations in the light intensity transmitted through the sound record o , and falling on the selenium cell, cause a corresponding variation of the sound membrane in the loud-sounding microphone or telephone, H .

In another method, by Mrs. Von Madeler, the sound record on the film is constituted by a wavy edge produced on the film. The sound

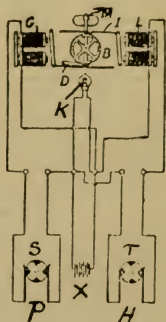


Fig. 4

box of the gramophone has to be actuated in proximity to the film. The style consists of a rotated cutter mounted on a pivoted bracket and vibrated by an arm, connected with the diaphragm of the sound box. The cutter is adjacent to the edge of the film and the sound-waves are thus recorded and represented by the wavy edge of the film produced by the cutter. As in the previous case, the sound record is taken while the film runs continu-

ously, either before or after the film is fed intermittently through the gate. A duplicate record may be simultaneously reproduced on the other edge of the film. To reproduce the sound record the sapphire or needle of the gramophone sound box has a flat end resting against the edge of the film. As it passes through the projector. The pressure of the needle is regulated by a balance weight. An alternative to the method of cutting the edge of the film by a rotary cutter consists in heating a platinum wire to a dull red heat sufficient to burn the edge of the film, and mounting this wire on an arm or frame connected with the diaphragm of the sound box, so that the vibrations of the wire may burn to a variable depth along the edges of the film. This method may be used to produce a film sound record of an ordinary disc record. With the above method the gramophone must obviously be near the camera and the projector, whereas by the photographic or photo-electric method the gramophone can be anywhere both in recording and reproducing. It is possible to use more than one gramophone, which is Rosenberg's method, devised more especially to compensate for the disturbing effect on the sound production due to the movement of the source of sound—say a speaker or actor. This dependency of the sound received, upon the movement and distance of the sound, is well instanced by the sound of a whistle of an approaching and passing train. To produce a more correct sound reproduction two microphones are used to produce a sound record on a film running at one side of the picture film. For reproduction, two sound-reproducing devices are put on either side of the screen. The films, both in the camera and projector, can

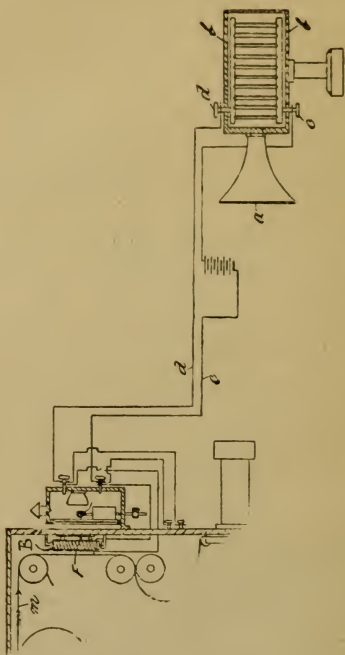


Fig. 5

be run from the same gearing, and the synchronism can be adjusted by having a movable gate carrying the sound-reproducing devices. A further advantage of having a reproducer on either side of the stage is that the sound appears to come from the correct side of the picture.

Mr. Von Madeler has recently been engaged in perfecting the method of directly coupling the projector and gramophone by intermediate shafting, which may be either rigid or flexible. In one method, the gramophone is driven from the picture machine through the shaft and bevel gears. The speed of the gramophone is limited by a governor which has means for setting it as desired. The shaft is telescopic and has a ball and socket joint to allow for lateral and vertical movement; the bayonet caps at either end link the shaft with the driving shaft of the projector and the gramophone shaft.

The talking movie in use today may be divided into two classes, one where the voice or other sound is photographed directly onto the motion picture film alongside the picture, the other where the voice or sound is recorded onto a wax record similar to a victor record.

In the first classification we have the De Forest Phonofilm, the Fox-Case Movietone and the General Electric Company's system. In the latter classification we have the Warner Bros. Vitaphone. While the method employed both in taking and projecting the picture is similar in all the systems, it will be as well to explain each system, as, while they have a lot in common, each of the systems vary a little from each other.

Let us first deal with the system perfected by Dr. Hoxie and controlled by the General Electric Company.

This process, the result of several years of experimenting in the General Engineering Laboratory of the company, means but slight change in standard motion picture projectors, since it involves only the addition of a sound-reproducing attachment and a loud speaker suitable for auditorium use. Both the picture and the sound are recorded on the same film.

One of the demonstrations has been with music to accompany feature films, the music being by a full concert orchestra. Development of this field requires no change in the technique of making the original film. After the original picture film has been made and titled, the accompanying music is played by a concert orchestra and is recorded on a film. The picture and sound records are then printed on one film in the proper time relation.

Another type has been the showing of singers and instrumentalists while they are presenting programs. Thus, when an orchestra is shown on the screen, it is possible to follow the playing of each musician, and see his actions on the screen and hear him. Even cymbals—among the most difficult to reproduce faithfully—sound like cymbals. Similar demonstrations have been made with vocal and instrumental soloists, with string and with vocal quartets, and with speakers.

To the casual observer the talking film does not differ from the usual motion picture positive. It is of standard width, but along the left margin there is a strip a small fraction of an inch wide on which is a series of horizontal light and dark bands and lines, of varying

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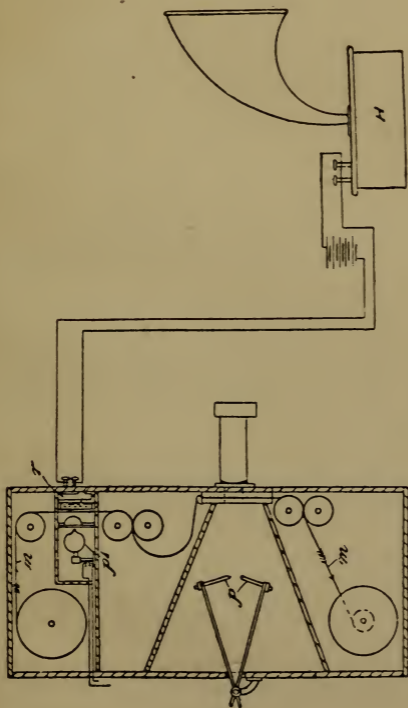


Fig. 6

widths and intensities. It is this series of bands and lines which produces the sound. The film is passed through the reproducer at constant speed, and, as these light and dark bands pass rapidly before a tiny slit in an optical system, the amount of light is varied. The ever-changing amount of light is received by a photoelectric cell—the electric eye—which is extremely sensitive to any change in the amount of light striking it. The more light received, the more current it will permit to pass through its circuit. This current is amplified and changed from electrical to audible energy by an amplifier and speaker.

At this early date, it is not possible to define the fields in which this new type of talking motion pictures will be of use. One of the first, however, will be in supplying a full orchestral accompaniment for pictures. The community picture house, accustomed to having a piano, or piano and violin, will be able to have the same music as the metropolitan theater.

Another field is offered by the news reels. Not only will it be possible to show important persons, but they can talk to the audience, and visiting notables can extend their greetings.

It has not been possible for famed musicians and orchestras to appear in small communities. The talking motion pictures will permit them to be both seen and heard throughout the country.

Educationally, there are also many ways in which the new apparatus will be of service. Many schools and colleges are already equipped with motion picture projectors as an aid in class-room work, and the new film will be

found of even more assistance. In the case of professors from abroad, it will be possible to record their lectures and demonstrations simultaneously, and to give their lectures the widest possible use by circulation of the film to colleges and universities throughout the country. Similarly, it will be possible to have an authority on the subject give a description to accompany any educational film for use in schools, the speech pointing out the important features of the picture simultaneously with their appearance on the screen.

These are but a few of the possible fields in which the new talking motion pictures will find applications. The list can, and will be expanded.

Outstanding among the features of the new apparatus are that both the picture and sound records are on the same standard motion picture film, and that a standard motion picture projector, with an attachment for the sound reproducer, is used. Since the picture and sound records are printed side by side on the film, it necessarily follows that the two must be properly timed or synchronized at all times—it is not possible for the picture to break and the sound to continue, or for the sound to stop and the picture to continue.

There are three principal elements in the apparatus, including a standard motion picture camera, a sound recorder and a standard motion picture projector with a sound reproducing attachment, all driven by synchronous motors. The pictures themselves are made in the usual way on standard film.

In recording the sounds, a microphone or sound collector of any desired type is employed, together with amplifiers. The micro-

phonic system actuates a tiny vibrating mirror which records the sound on the film as light and dark bands, the light from a small incandescent lamp being reflected by the mirror through a tiny slit in the optical system in front of the film. The higher the pitch of note, the higher its frequency—and the greater the frequency of vibrations of the mirror which faithfully reproduces each sound vibration as a mark on the film.

The sound record can be made in different ways. Both the picture and sound can be simultaneously recorded on the same film by mounting the two recording elements as a unit, with the sound recorder uppermost. The two recorders can also be mounted separately and the sound and picture film negatives made as individual units, such an arrangement being preferable when the pictures are being made in studios and when the camera is being shifted constantly. Again, as in the case of accompanying music, the picture film can be entirely finished and titled, the record of the music then being made on a separate film and the two combined on the finished positive.

Fig. 7 shows a scene in the General Engineering Laboratory studio, recording voice and picture. The room walls are covered with monk's cloth to prevent echo. The microphone, which may be placed inconspicuously, picks up sound waves and carries them, after amplification, to the recording unit in an adjoining room.

The sound re-producing attachment which is connected to the standard motion picture projector consists of a photoelectric cell behind the film and a small electric lamp with suitable optical arrangement in front of the film.



Fig. 7

As the film passes a small slit, similar to the one used in making the sound record, a varying amount of light is admitted to the photo-electric cell, the amount of light depending on the photographic density on the sound

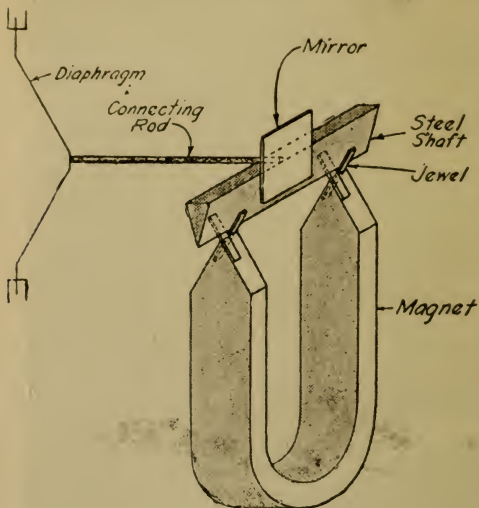


Fig. 8

track. The result is that a very minute and varying current, an exact replica of the sound wave, is produced. This tiny current is amplified and led to a loud speaker which reproduces the sound in sufficient volume to fill the auditorium. Any suitable loud speaker may be employed.

Examine one of Hoxie's films carefully.

Here is the usual series of pictures of actors and actresses. At one side of the pictures is a strip of bands. Some of the bands are fairly dark; others are light; still others are nearly transparent. No two bands are quite alike in density. Examine them under the microscope and the differences are still more apparent—glaring, in fact.

In the Pallophotophone a mirror fastened to a steel shaft is connected by a rod with the diaphragm of a telephone-like sound-collector. The shaft rocks on jewel bearings and is held in position by a permanent magnet. Diaphragm, connecting rod, mirror and shaft, here greatly enlarged, weigh about one quarter as much as the head of a pin. *Fig. 8.*

These bands are sound records made simultaneously with the series of pictures on the film. Light rays made these bands. Sound must therefore have been in some way impressed on the rays. Similarly light must in some way convert the bands back again into sound. To perform this miracle we need a sound-light or light-sound converter, just as we need a needle to dig a record into a phonograph disk and another to translate the dug record into sound.

Conversion of Sound Into Light

This conversion of sound into light impulses is made possible by a photo-electric cell, which looks very much like a radio vacuum tube and has some of a radio tube's properties. Such a cell varies in electrical conductivity with the intensity of the light that happens to fall upon it at any instant. Without the photo-electric cell a talking motion picture is inconceivable to an engineer.

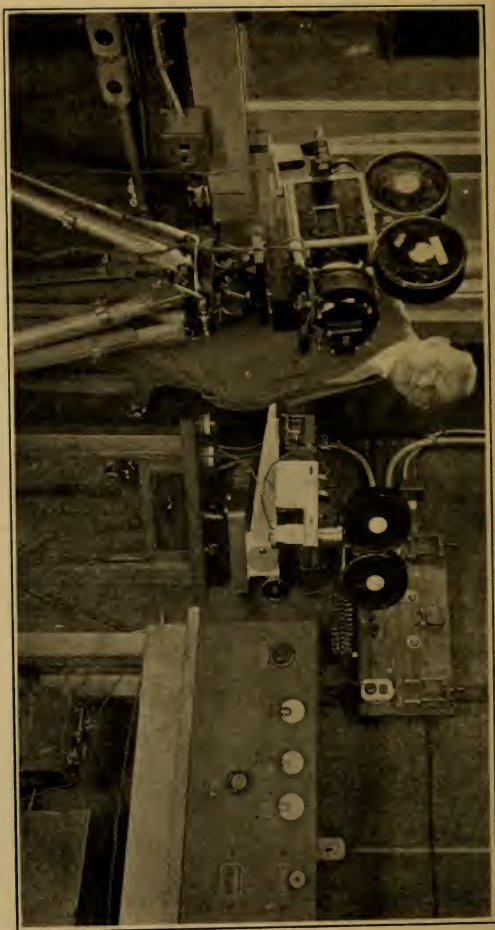


Fig. 9

In the simplest imaginable talking film we have a lamp or other source of light which forms part of a telephone speaking circuit. We say "hello." The light flickers imperceptibly. Its rays are thrown on a moving film. Each flicker corresponding with a sound element in "hello" is photographed. On the film, after development, a series of parallel bands appear, some darker than others, no two exactly alike. This is a photographic sound record of "hello."

To reproduce this sound record we need the photoelectric cell. Light rays are focused by lenses on the film as it moves. The rays pass more readily through the lighter than through the darker bands. Thus the original flickers are reproduced. After passing through the film the rays fall on a photoelectric cell which forms part of a telephone circuit in which a loudspeaker is included. The cell fluctuates in conductivity with the flickers produced by the bands as the light streams through them. Although the flickers may range from less than one a second to more than ten thousand a second the cell responds instantly. Electric impulses are set up in the telephone circuit, impulses which are now strong, now weak. The diaphragm of the loud-speaker is thus made to vibrate back and forth and to beat the air. Sound waves are generated. We hear the word "hello."

Fig. 9 shows the two recording instruments. Left—standard motion picture camera with synchronous motor drive; right—sound recorder.

This, in brief, is the fundamental principle

of all systems in which sound is recorded photographically on a moving picture film. It is a principle which is almost as old as the motion picture itself. Hardly had the screen play captured the fancy of the world than inventors began to ask themselves: Is the motion picture destined to remain forever a photographic dumb show? Can't these gesticulating men and women be made to talk, sing, laugh and shriek as they seem to be doing? Can't some sort of sound record be made simultaneously with the picture?

For years little progress was made in finding the answer to these questions because there was no satisfactory photoelectric cell. Light-sensitive cells of selenium were tried, selenium being markedly affected electrically by light rays. But selenium was too slow. It could not respond hundreds and thousands of times a second to light fluctuations. Then came the war, and with it a wonderful development of vacuum tubes. A way was found of using potassium with a tube to produce a marvelously sensitive photo-electric cell with a response practically instantaneous. With that development the problem of the motion picture was solved. Synchronization of sound and action is merely a matter of engineering ingenuity.

After the photoelectric cell was perfected inventors of talking motion picture machines blossomed forth as never before. Most of them conceived the idea of incorporating an electric arc or lamp in a speaking circuit and causing the light to fluctuate with the voice in the manner already described; the sound record thus obtained on the film was reproduced with the aid of the cell. Several of these more or less identical methods of caus-

ing a light to fluctuate are highly successful.

Hoxie proceeded along a different and a more difficult path. His light is not incorporated in the telephone circuit at all. It glows constantly outside the circuit. Its beams fall upon a mirror which is directly connected with the sound-collector. Thus, in the pallophotophone, which is one form of sound-collector devised by Hoxie, the mirror literally forms part of the telephone diaphragm, since the two are physically connected. Hence, as the diaphragm moves in response to the voice the mirror must also move. If the diaphragm vibrates 5,000 times a second in response to the high, shrill note of a piccolo the mirror rocks 5,000 times a second. The beams from the constantly glowing light focused on the mirror by a lens are reflected on the film through a slot one-one thousandth of an inch wide and one-tenth of an inch long. Hence the sound record appears as a series of slot-shaped bands.

In the projection machine a similar mirror catches the rays as they travel from a small lamp through the film and throws them on a photoelectric cell, by which, as we have seen, they are converted into telephone currents made audible by a loud speaker to a whole auditorium.

On purely practical grounds almost any engineer would proclaim it utterly impossible to make motion pictures talk with such mirrors. Since the mirrors are physically moved for very feeble currents they must be of an unattainable diaphanous lightness. Hoxie knew this, but was not daunted. Even in some of the most delicate measuring instruments known to science, mirrors as small and light as Hoxie's are not to be found. The mirror of

Hoxie's pallophotophone weighs only one-quarter as much as a pinhead, or one-twelfth as much as a whole pin, and this includes the infinitesimal diaphragm of the sound-collecting device and the rod and shaft that rock the mirror. So light is a mirror that a zephyr would blow it from the hand. It must be handled with tweezers. Fingers are too coarse.

The secret of Hoxie's success lies largely in the extraordinary lightness of his mirrors and the parts that rock them and make them reflect beams of light on a film or on a photo-electric cell. So sensitive are the sound-collectors and mirrors of Hoxie's recording machine that whispers can be picked up from a distance of seventy-five feet and translated into bands on a film. Clearly, the direction of a talking motion picture requires a new and very exacting technique. The actors must be perfect before the director shouts "Camera!!"—perfect in action, perfect in elocution. As the film is unreeled during the making of the picture the director must exercise all the fortitude and self-restraint of which he is possessed. There may be no bellowed instructions. Even the rustling of a sheet of paper or the sighing of the wind in the trees is recorded. Yet, despite the delicacy of response, the mirror of the Hoxie sound collector is not shaken out of place or deranged by the blaring of a brass band of a hundred pieces.

It must not be supposed that the apparatus for photographing sounds according to Hoxie's principles forms part and parcel of the camera on "location." The machine for taking the picture and the machine for recording collected music or speech are separate. Both are driven

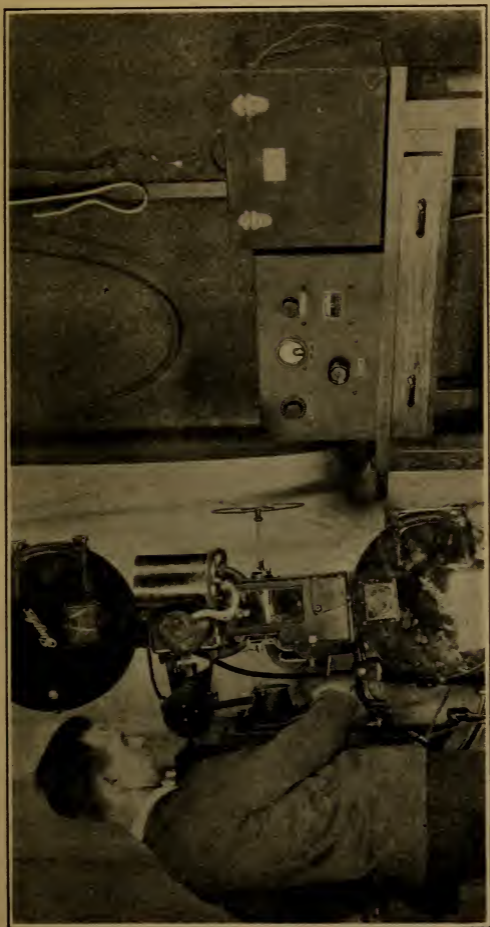


Fig. 10

by electric motors, but the motors are accurately synchronized. Two separate negatives are obtained—the one a tenth of an inch wide, constituting the sound record, the other seven-eighths of an inch wide, constituting the play or the scene. The two are printed side by side on a single strip of a film. Since sound and action are on one film there can be no mistake either in synchronization or in tempo. A reel is projected at the standard speed of sixteen pictures a second; the time of the music must necessarily be correct.

Fig. 10 shows combination sound and picture projector. A standard projector is used, the sound-reproducing element being mounted directly below the upper drum which holds the film.

Separate machines for recording sound and making pictures are necessary because of the delicacy of Hoxie's mirrors. The turning of gears in a camera is enough to produce vibrations which would affect a mirror and connections which are light as thistledown.

Hoxie has developed three different pieces of apparatus to meet the different conditions encountered in making and projecting talking motion pictures. These are the pallophotophone, the pallotrope, and the photophone. Both pallophotophone and pallotrope record sound photographically on a film. The photophone is simply an attachment to an ordinary projection machine; it reconverts the photographed bands on the film into sound.

In the pallophotophone the mirror, vibrated by the speaking or singing voice picked up by

a microphone, records sound directly on a film without the aid of a photo-electric cell. In the pallotrope the light from the mirror, actuated by a sound collector, falls first on a photo-electric cell. The fluctuations in current produced in the cell cause a second distant mirror system to oscillate and record light reflections as bands on a film.

The opposite side of standard motion picture projector with sound-reproducing element, showing additional details of sound-reproducer is shown in Fig. 11.

Whether the pallophotophone or the pallotrope shall be used is dictated by the conditions that prevail. When it is advisable to record sound at some distance from "location" the pallotrope is the apparatus used. Here it may be mentioned that "pallo" is of Greek origin and means moving or dancing. It is in truth a dancing light that makes the record and reconverts it into sound.

The photophone, which is attached to the projector and which is the sound translator, is small enough to be carried in an ordinary valise. Here a slot similar in size and shape to that of the recording machine is to be found. The film passes across the slot. Light from a lamp passes through the film and falls on the photo-electric cell, after which the loud-speaker does the rest.

Vacuum tube amplifiers, with which millions of radio listeners are now familiar, are used both in recording and reproducing sound. Feeble telephone currents are thus magnified tremendously. Amplification is particularly

important in reproduction. The loud-speaker must fill the auditorium or theatre with music of full, natural volume, and only by amplification and a correctly designed loud-speaker can that be attained.

The sound record, as we have seen, appears at one side of the film, and this film is moved intermittently across the projecting lens. Sixteen pictures are jerked in a second past this lens. But music on the film must flow continuously; there must be no jerks. To overcome this difficulty sound is produced from a part of the film which is in continuous movement. Hence the sound record does not appear actually adjacent to the appropriate pictures but a foot or more away from them. A little judgment is required to print the sound-bands and the pictures in the proper relative positions to obtain the desired synchronization.

Motion pictures can be made to talk realistically by synchronizing phonograph disks with cameras and projection machines, but the synchronizing method is complicated. By recording sound directly on the film there is an obvious gain in simplicity. The tin in which the film is shipped also contains the appropriate music. If a film should break during projection, which occasionally happens, synchronization is not destroyed when repairs are made. Half a dozen torn pictures may be deleted, but so are the accompanying bars of music—no more and no less.

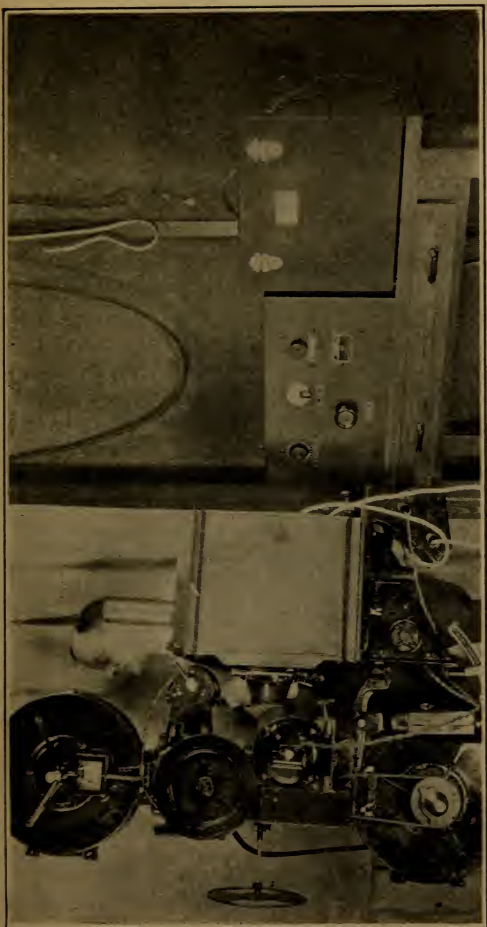


Fig. 11

PHONOFILM

We shall now pass on to the system developed by Dr. Lee De Forest, known as the Phonofilm, this was the first of the talking movies where the sound was recorded on the film, to reach Broadway. Perhaps it will be as well to let Dr. De Forest himself explain his system.

My attention was focused on the field of talking motion pictures, wholly by photographic recording in 1918. Perhaps the one consideration which, more than any other, prompted me to enter this field was my desire to personally develop a new and useful application of the audion amplifier. One which I could expect to develop largely by my own efforts, as distinguished from its application to long distance telephony, where obviously the intensive efforts of large corps of engineers, backed by a gigantic business organization, were indispensable. Another motive was my desire to possess a phono-graphic device which would be free of many of the inherent shortcomings of the disc machine, notably the short length of record, the necessity for frequent changing of needles, and the belief that by means of a pencil of light instead of a steel needle it might be possible to completely escape from the surface scratch which has always been inseparable from the existing types of phonograph.

But at the beginning of my work I laid down several principles, based wholly on commercial considerations, limitations which I considered the talking motion picture must, in order to be commercially successful, fall within. These considerations were—

First, nothing but a single standard cinematograph film should be employed.

Second, the speed must be that of the standard motion picture film.

Third, the recording and reproducing devices must be absolutely inertialess, excepting possibly the diaphragm for receiving and the diaphragm for reproducing the sound.

Fourth, the receiving device must be sufficiently sensitive to permit its being successfully concealed at a reasonable distance from the speaker or source of music to be photographed.

Fifth the reproduction must be as good, or better, than the existing phonograph, and loud enough to fill any theatre where the talking pictures should be exhibited.

Sixth, the photographic sound record must be so narrow as not to materially cut down the size of the normal picture projected on the screen.

Seventh, the photographic record, therefore, must be one in which the *width* or *amplitude* on the film was constant throughout, and the sound variations must therefore be photographed as variations in density in the photographic image. In other words, the light record should be in the form of exceedingly fine lines or parallel bands of varying densities all of the same length, and lying always transverse to the direction of the motion of the film.

To photograph the highest harmonies of any music which it might be desired to record upon a film traveling at normal speed, i.e., 12 to 16 inches per second, necessitated a slit not more than two thousandths of an inch in width. And in order not to appreciably cut into the size of the picture the length of this slit must

not exceed at most three thirty-seconds of an inch. This in turn necessitated the employment of an intense light source, small enough to go inside the moving picture camera, and yet one whose intensity could instantly and proportionately be varied by the slightest and fastest sound vibrations which it might be desired to record. Some of the above conditions, it will now be admitted, were by no means easy of realization.

Early in the spring of 1919 I filed patent applications on the methods which I believed would accomplish the above laid-down conditions, and began actual research on the various means which might be successfully employed. At that time I figured that the work involved should require about two years. The work has been almost uninterrupted, and of the most exacting and discouraging nature. Literally hundreds of experiments have been made, and many thousands of feet of films have been photographed, only to be thrown away.

I well remember the grim satisfaction I felt when, for the first time in reproducing a photographic record of my voice, I was able clearly to determine whether or not it was being run backwards.

At the start I undertook to photograph the light fluctuations from three different sources. First, that of the speaking flame, second, that from a tiny incandescent lamp filament. To determine whether or not the radiation from these sources were faithfully following the voice I first exposed the photo-electric cell to their light and listened to the reproduction after it had been many times amplified by the audion in a telephone receiver. I found that both these sources were capable of reproduc-

ing voice and music with astonishing fidelity. This was after many refinements in learning how best to apply the voice to fluctuate the flame, and to secure sufficiently rapid cooling of the extremely short incandescent filament to permit the light from the latter to follow the voice frequencies up to three thousand per second. But to my disappointment I then found that to photograph these light variations which were producing such perfect reproduction in the photo-electric cells was an entirely different proposition. A photo-electric cell is far more sensitive than the most rapid photographic emulsion, requiring for translation far less percentage of the variation of the normal light of the source to produce a sufficient change in the electric conductivity of the cell, than is necessary to produce for recording corresponding changes in density in the photographic image.

The other of the three methods which I originally set out to develop, although far less simple and more difficult of attainment proved in the end the practical method for producing by electrical means light fluctuations of sufficient amplitude to be photographed in every *necessary* degree of intensity.

The light that I employed for this purpose was that of a gas-filled tube excited by high frequency current. It was not difficult to construct a gas-filled tube giving such a light when excited by a high frequency current from a small radio telephone transmitter. But it was no easy task to design such a tube which could, when connected to a small 5 or 10 watt high-frequency apparatus, generate a sufficient light to photograph all necessary variations of intensity upon a narrow strip of standard emul-

sion film, moving at the rate of 12 to 16 inches per second in front of a slit, one and one half, or two thousandths, of an inch wide.

Having now briefly outlined the general principles employed in developing the Phonofilm, a clearer understanding will be obtained if I outline briefly step by step the various instrumentalities employed from the original source of sound to its reproduction alongside of the picture upon the silver screen. The voice transmitter is designed to transform into electric currents the lightest and the strongest sound waves which may be spoken or played within five to twenty feet from the device. Telephonic currents thus generated are naturally exceedingly weak, and must be amplified through a series of audions to the order of several hundred thousand times their original magnitude in order to effectively modulate the high frequency currents which are being generated in the small oscillator. This oscillator is a form of the radio telephone with which you are all more or less familiar. Connected to this high frequency output circuit is a gas filled tube which I have called the "Photion." This tube glows at all times with a violet light which is highly actinic in quality. The intensity of this light increases and decreases around its normal brilliance in exact correspondence with the modulated high frequency energy of the oscillator. The light from the end of this tube is focused by means of a lens upon the very fine slit directly upon the emulsion side of the film. This Photion lamp is placed inside the moving picture camera at a point where the film is moving

continuously some ten inches away from the window of the camera, at which point the motion of the film is, as you all know, intermittent for the purpose of photographing the picture. The combined picture and sound record thus made are, of course, in absolute fixed relation to each other and there is consequently no problem of synchronization to be solved. It is only necessary that in the projecting apparatus in a moving picture theatre the sound reproducing device shall be the same distance from the picture aperture, measured in inches along the film, as was the case in the moving picture camera where the voice and the picture were originally photographed. .

Between the upper film magazine and the intermittent, step-by-step, mechanism of the standard moving picture projector machine are located in two small co-axial metal tubes, the sound projector lamp and the photo-electric cell. The light from this small lamp is focused through a fine slit having the same dimensions as that in the camera, upon the photo-electric cell, which is a few inches in front of the slit. Across the slit and in close contact therewith passes the film on which the original photographic image of the sound has been photographed and printed. The fine lines of light and dark, which represent the sound record, passing across this tiny slit produce corresponding variations in the light beam which transverses the slit and falls upon the photo-electric cell. Now in series with this photo-electric cell are connected a dry battery and the grid and filament of the first audion of a specially designed five-step audio-frequency amplifier. This amplifier, which has been designed with the utmost care to avoid any form of distortion, magnifies the minute tele-

TALKING MOVIES

phonic currents thus generated in the photo-electric cell, by the order of a hundred thousand times. The output circuit of this amplifier is then connected by means of electric wires to the loud speakers which are concealed behind, or directly around the screen, on which at the same time the original picture is being projected.

Note now the all-important part which the audion plays in the talking motion picture, or as I prefer to call it the Phonofilm. First, we have an amplification of the order of five thousand to one hundred thousand times of the original telephonic currents, then an oscillating audion generating the high-frequency energy for lighting the Photin tube, and another audion, acting as modulator to control the high frequency output of this oscillator. Then at the reproducer we have again a multi-stage audion amplifier, thus giving in all an amplification, from the original transmitter near the camera to the final loud speaker at the projection screen, of the order of several million times. I do not mean by this to state that the reproduced voice you will hear is several million times as loud as the voice that made the record! There is between the photographing of the voice on the film and its reproduction in the photo-electric cell, a very great diminution in intensity, which diminution must be made good, and in addition amplified thousands of times in order to permit the loud sound which is required to fill the auditorium.

I have employed two types of photo-electric cells with my reproducer. The so-called Kuntze, potassium-mirror, photo-electric cell, and the less known but more sensitive and

reliable "Thallafide" cell of Theodore W. Case. This latter cell has been perfected after many months of most painstaking, scientific research by Mr. Case, until it is unquestionably the complete answer to the problem of how to obtain electrical from light variations, at least where one has a choice of light wave-lengths in which to work. The Thallafide cell is most sensitive to the infra-red and red radiations. It was used to excellent purpose in the Case system of secret signalling during the latter part of the great war. (The lack of sensitiveness and well known lag in response, or fatigue, of selenium, is such that no *well-informed* designer of photo-electric apparatus for rapid signalling would to-day consider the employment of selenium.)

I wish here to acknowledge my indebtedness to Mr. T. W. Case, not only for his contribution of the beautifully suitable Thallafide cell, but for many very valuable suggestions, as well as practical laboratory assistance, in the latter course of my experimental work.

It has for a long time been realized by telephone and acoustic engineers that the necessity for a diaphragm at the transmitter introduces at the very outset of the sound translation problem a source of distortion and imperfection. It is the diaphragm more than any other element which introduces the deformities in recording and in reproducing voice and music on the phonograph as well as in telephone transmission. Therefore for many years efforts of telephone and phonograph engineers have been devoted to reducing as far as possible distortions thus introduced by the natural period of vibration of the diaphragm, or membrane, against which the sound waves impinge.

But these engineers it would appear have not looked elsewhere in the realm of physics with sufficient scrutiny. Otherwise we should long ago have been free of the necessity for using any diaphragm whatsoever at the transmitter element of apparatus, the object of which is to translate sound into electric currents with the minimum possible distortion, regardless of the expense or the elaborateness of the apparatus thereby involved. (I do not here refer to the ordinary microphone transmitter, millions of which are in use thruout the world, and which must necessarily be as simple and cheap as possible. For such telephone apparatus the carbon microphone with diaphragm may possibly always be used.)

But where exact and accurate translation of sound waves into electric currents is desired it is quite necessary to use a vibrating diaphragm. It has long been the dream of telephone engineers to translate the sound waves in the air directly into electric currents. There are, I have found, a variety of ways of doing this. You are perhaps familiar with the story of the discovery of the audion; how the first suggestion came to me as a result of observation of a sensitive gas flame. From this rudimentary idea, which originated in 1900, was developed, during the ensuing five years, the three-electrode vacuum tube which was destined to become the telephone repeater or amplifier for which telephone engineers had been searching for twenty years. For these were working always along the well beaten path of a telephone receiver siameesed by some more or less ingenious method to a carbon microphone transmitter controlling a local source of electric energy.

And now in exactly the same way, starting from exactly the same point of investigation, the sensitive gas flame, has been evolved a new form of microphone device, which does directly what the telephone engineers have so long dreamed of accomplishing, that is, turning sound waves in the air directly into electric currents. Take the ordinary bat-wing gas burner, or a certain form of Welsbach mantel gas light, or special forms of oxy-acetylene gas flame; insert two heat-resisting electrodes therein, in proper relation to the flame and to each other; connect these electrodes to appropriate electromotive force. You will then have an extremely sensitive sound converter which gives an electric reproduction of the sound waves in the air enveloping the flame which is of an entirely different order of fidelity from that ever obtained from any form of microphonic device using a diaphragm, whether this be of the carbon, electro-magnetic, or electro-static variety. Here again history repeats itself. After I had first used the gas flame as a detector of wireless signals I next tried the intensely heated gases in an electric arc and found the same phenomena, although very imperfect on account of the over-whelmingly loud disturbances due to the arc itself. So again it has been found that a long electric arc in the air possesses the property of modulating to some extent the electric current passing between the electrodes in response to the changes of air pressure produced by the impinging sound waves.

In Germany an investigator by the name of Vogt has found a similar action in the ionic currents passing through the air between a Nernst glower and a cold anode placed near-

by. All of these electric reproductions of sound waves are naturally extremely weak, and must be amplified, by means of a series of audion amplifiers, several thousand times before they can be applied to any useful purpose.

More recently, Dr. Philip Thomas, of Pittsburgh, has demonstrated that a high-potential low current discharge between two electrodes in air may be "modulated" by sound waves. This is a return to the method which I showed in a patent taken out in 1906 for controlling very simply by the voice the high-frequency high-potential currents in a radio-telephone transmitter.

But I have found still another method of translating sound waves direct into electric currents without the imposition of any diaphragm. This arrangement, independently suggested by Mr. T. W. Case, is the reversal of the well known "Thermophone," a device wherein an extremely fine platinum wire, thru which is passed a telephonic current, reproduces these in the form of sound waves due to the alternate heating and cooling of the air immediately surrounding the extremely fine wire.

We have found in the same way that when a series of very fine and very short platinum wires are heated to a dull red from a local source of current, the resistance of these wires changes, alternately increasing and decreasing in conformity with the sound waves impinging thereon; so that from a telephone transformer connected in series with the battery and this thermo-microphone, a remarkably faithful representation of the sound waves is obtained, even though the frequency of these be as high as 3000 per second. The sensitiveness of this

device is greatly enhanced by a gentle stream of air, by fluid evaporation in the neighborhood, and by other auxiliary means. In a word, therefore, there now exist several ways of obtaining extraordinarily faithful reproductions of sound waves in the form of electric currents, entirely unlike the diaphragm method on which telephone engineers have been working from the beginning of the telephone art.

Of all the diaphragm types of transmitters unquestionably the electro-type, as perfected by engineers of the Western Electric Company, comes nearest to approximating perfection. While this is extremely insensitive compared with the best carbon microphone type, there is small comparison between the fidelity of reproduction by the two means. But one listening in a telephone to the reproduction by means of the flame microphone, and then by means of the electro-static microphone, will at once exclaim that the fidelity of reproductions in the first case is of quite a different order from that obtained even from the highly perfected diaphragm of the best electro-static microphone.

Passing now to the loud speaker, or reproducer, the last step in the many translations which I have been describing, I regret to say that we are here still limited to the use of a diaphragm and horn. Although the loud speaker has been developed to a high state of perfection, notably again by engineers of the Western Electric Company, there is still room for improvement and much is left to be desired. And I am convinced that final perfection will come not thru any refinements of the telephone and diaphragm, but by the application of entirely different principles. For ex-

ample the talking arc has been known for many years as a fairly faithful converter of telephonic currents into sound waves; and recently I have done some development work along the lines of the "loud-speaker thermophone"; but thus far with no very promising results. Some entirely novel method of agitating the air waves, as distinguished from the thus far single useful method of beating them by means of a solid diaphragm, must be discovered. For the present, however, the form of telephone loud speaker with properly designed horn, answers the actual requirements well, if not perfectly.

The question is often asked, "What happens when the **film becomes torn**? Is not **synchronism** lost in a film that has been patched together??" Where **pictures** are taken, as here, at the rate of 20 to 22 per second, one or even two "frames" may be cut out of both voice and picture records without the flaw in exact synchronism being observable. This holds true even though the picture is some ten inches ahead of the corresponding voice record. However the sharpest ear will not notice the omission from a voice or music record of a portion occupying not more than one twentieth part of a second.

Of course should a film become badly torn, or worn out, it must be replaced by a fresh print, as in any motion-picture film.

We have often heard comparisons of light with sounds. Here, on the Phonofilm, we have them both truly interlinked—Sound registered and interrupted by Light—Light waves have become the carriers of sound waves. and we have here caused Sound to write its autograph in Light.

These symmetrically beautiful, but ever-varying lines of light are indeed "sound shadows"—long sought by the poets—"photographic echoes" which can resound and reverberate, and re-echo, again and again, with all true color of tone and fidelity of phrasing, whenever it pleases one to again pass light athwart these shadows!

In studio practise with Phonofilm recording new methods must be introduced in contrast to those heretofore employed in the ordinary motion picture. For example, everyone must work in absolute silence, except the actors or musicians who are being actually recorded. This involves, of course, studios particularly designed for this work every precaution taken against extraneous noises and interior which has heretofore distinguished the moving picture studio must be completely eliminated during a "take."

A new type of moving picture director must be evolved, or if the old type is continued he must be thoroughly gagged, and learn to direct by signal and gesture only. Special means must be taken to shield the highly sensitive transmitters and amplifiers from electric induction from the various types of lamps which must be employed and the cables leading thereto. However these difficulties are not insurmountable nor really serious. We have made great progress along this line, and our productions are each week coming nearer to the ideals we have set ourselves to work towards.

There is no reason why the Phonofilm process cannot be used with one or two of the better colored-picture methods. Already steps have been taken to combine the Phonofilm

with color, and we expect to be able to release films combining this doubly charming novelty within a few months.

We believe this will mark a great advance towards that perfect realism on the silver screen of which we have all dreamed, but which in its perfection can never be attained.

I have now equipped a Bell-Howell camera with the Photion attachment which, combined with a specially built portable transmitter and amplifier unit, will permit of the Phonofilming of outdoor subjects. For example open air band concerts, pictures of waterfalls, ocean surf, singing birds, and similar subjects where nature has combined the beauties of sound and form.

Having now run over briefly the evolution of the methods of recording and reproducing sound photographically on the moving picture film it is appropriate to direct your consideration to some of the useful commercial and educational applications of this principle, and also of the many inventions which the development of this principle have entailed. These questions have doubtless been passing thru your minds since the topic of talking motion pictures was first called to your attention:—"Does the public want the talking picture? Is there room in the field of the silent drama for screen versions which are not all merely pantomime?" "Can the picture and the sound which go together so naturally in actual life, and which have been so completely divorced from each other since the beginning of the cinema art, be again brought together in a manner which shall be, if not entirely natural, at least artistic and pleasing?"

If you ask whether the ordinary silent

drama to which we are all so familiarized can in general be improved by the addition of the voice, the answer is unquestionably "No." Many, and in fact most of the moving picture artists are not trained on the legitimate stage; they have no adequate speaking voices—many in fact are incapable of speaking good English. The situation is exactly like that existing when the moving picture was first evolved. It was then the common idea that the moving picture drama would be nothing more than an attempt to photograph the ordinary drama of the stage, limited to the same confined situations, the same small scenes, the same few characters, etc. It did not take long to demonstrate the total failure of the new motion picture art to enter into successful competition with the drama along these lines. An entirely novel type of dramatic scheme and presentation was necessary before screen versions were artistically possible. But Edison, and the other moving picture pioneers, had supplied a new medium, and it did not take the more enterprising, energetic, and progressive producers long to see the entirely new possibilities which thus lay open to them, and to evolve an entirely new form of entertainment. How well they have succeeded in evolving a new art is attested by the immense financial success of the moving picture industry of today.

The situation therefore, as regards the future of the Phonofilm, is today very similar to that which faced the new art of the silent picture when it was first realized that in order to fulfill its mission as a means of entertainment and education, it must not seek to follow blindly in the path of the legitimate drama. That it must take full advantage of the im-

mensely wider ranges which were inherently its own property, and enter entirely new fields which were, by the very nature of things, completely closed to the older form of stage pictures and stage entertainment. Thus I claim that an entirely new form of screen drama can be worked out, taking advantage of the possibilities of introducing music and voice, and appropriate acoustic effects, not necessarily thruout the entire action, but here and there where the effects can be made much more startling, or theatrical if you will, or significant than is possible by pantomime alone, no matter how cleverly such may be worked out. It is incumbent on the scenario writers to see these possibilities, and to work up their situations and scenes around such acoustic effects as can be successfully brought out, rather than to follow the reverse principle of merely attempting to introduce acoustic effects into scenes and situations which were primarily better adapted to the pantomime art.

To reproduce in an artistic and pleasing manner, both musically and pictorially, operettas, entire acts of opera, selections by symphony orchestras, popular bands, the songs of concert singers whom the public admires but are seldom privileged to actually hear—really popularize the playing of famous virtuosos, on piano or violin—there can be, I believe, no question as to the long felt vacant field which the Phonofilm is destined to fill. For here surely the silent drama is totally lacking; and the too brief phonograph record, blind to sight, and leaving much to be desired in naturalness of tone quality, can never be expected to qualify as a means of entertainment of public audiences.

There are, moreover, many instances where the silent drama, as it actually exists today, can be improved by the introduction of spoken matter. And numberless cases where incidental music, which can be played only by adequate orchestras available solely in a few of the largest theatres, can be successfully introduced into every medium-sized moving picture theatre in the land. Similarly where the action and sequence of so many silent dramas are today badly interrupted by the necessity of reading long and elaborate titles and explanations on the screen. The reading of lengthy letters, telegrams, etc., could frequently be far more effectively rendered by a clear resonant voice, spoken; it may be entirely off the scene, and not necessarily by one of the principals. I can in fact picture some very dramatic effects which may be obtained where, perhaps, only one or two words or sentences spoken throughout the entire run of an otherwise silent drama, will grip the attention, and startle the imagination, as does the occasional introduction of a hand-tinted object in an otherwise monotonous black and white picture.

I intend here only to point out that there lie dormant in the Phonofilm new possibilities for obtaining dramatic and genuinely artistic and beautiful effects, which lie entirely out of the range of the silent drama. It is rather for the progressive and imaginative producers and scenario writers to act on these hints to evolve something which the public has for a long time, in an inarticulate and half recognized manner, been expecting. To those who have the requisite daring and initiative will come the greatest meed of reward.

So much for the Phonofilm drama. But

there are other fields for the useful combination of picture with voice and music which can admit of no serious dispute. Foremost in this category I would place the educational film. Unquestionably most of the educational films, especially for class room work, could be greatly improved in interest to the audience and in clarity of the lesson conveyed, if their presentation were accompanied by a lucid explanation, delivered in the first place by some authority on the subject who is far more competent to lecture thereon than are the majority of the instructors who are presenting the film to their classes. The proper matter, concise and to the point, will thus always accompany the picture, not too much and not too brief; and information be thus conveyed which the picture alone is quite inadequate to confer.

Similarly in the presentation of scenic films, travelogues, etc. Their interest and beauty can be immeasurably enhanced by virtue of verbal descriptions couched in impressive, and sometimes poetic terms. Consider moreover the appeal of fine pictures of the great Outdoors, the vision of wide horizons, views from some mighty mountain top,—the emotions awakened in the heart of the Artist who gazes out upon some noble forest landscape or over the magnificent vistas of far reaching valleys, the deep sentiments which are aroused when one stands beneath the trees of some lofty cathedral grove! These sentiments, these emotions, can only be adequately expressed by appropriate music, or perchance to the accompaniment of the poem of some great master. All such music and all such poetry can now be interwoven with the picture; and its beauty and its message thereby elevated to

ennobling heights, to which the silent picture, however lovely, has never yet attained.

The weekly News Items which are now recognized as an appropriate part of every film program can be made vastly more interesting and informative to the audience if, in a few terse sentences, the scene depicted be also described, or the situation, which is frequently so inadequately told by the picture alone, be interpreted by the voice of some well informed, entirely invisible, speaker. Once this form of pictorial news service has been adequately introduced, I venture to say that the average audience will feel that without the spoken accompaniment, these pictures have lost their grip their lively interest.

In the realm of the comedy immense possibilities for the Phonofilm unquestionably lie. The humor of many ludicrous situations can be screamingly increased if the right words, the right jest were spoken at the right time, in the proper dialect, or vernacular, or tone of voice. Similarly in animated cartoons, where the little animals or manikins can speak their funny thoughts as well as act in their funny ways, the humor of this new type of comedy can be readily doubled.

The filming of notable men, characters in the public eye, presidents and rulers, candidates for public office, etc., will be made many fold more interesting and genuine to the audience when their voices also are reproduced, instead of the present more or less inane mockery of their moving lips accompanied by silence. Picture for a moment what the Phonofilm will mean in the future in perpetuating our really great men for coming generations—How priceless now would be the film reproduction of

Lincoln delivering his immortal Address at Gettysburg, or of Roosevelt as he stood before the Hippodrome audience at his last public appearance delivering a message to his countrymen, the inspiration of which has already been, how sadly, lost. Could we now see and hear Edwin Booth as Hamlet; Irving as Richelieu; Mary Anderson as Juliet—for real comparison, not based on treacherous and fading memories, with our present day “great” tragedians! None can deny the need to our present thoughtless generation of frequently seeing and hearing in their exalted moments our really great men reproduced from time to time for the benefit and uplift and inspiration of us all. That these great moments in the lives of great men shall not be forever lost to our descendants, is one of the debts which those who come after us shall owe to the film which records both the voice and the visage of the nation’s leaders.

“MOVIETONE”

The Fox-Case Corporation is responsible for the introduction of the “MOVIETONE”. The system was developed by Theodore W. Case in the Case Research Laboratories in Auburn, N. Y.

Movietone probably had its inception back in 1910, when Mr. Theodore W. Case, then a student of Yale University considered photographing sound and reproducing it by means of selenium cells. These experiments were not carried to a practical point due to the fact that selenium was not satisfactory as a reproducing cell, and also due to the fact that amplifiers and loud speakers as we now know them were unknown.

MOVIETONE CAMERA THAT TAKES A PICTURE OF SOUND

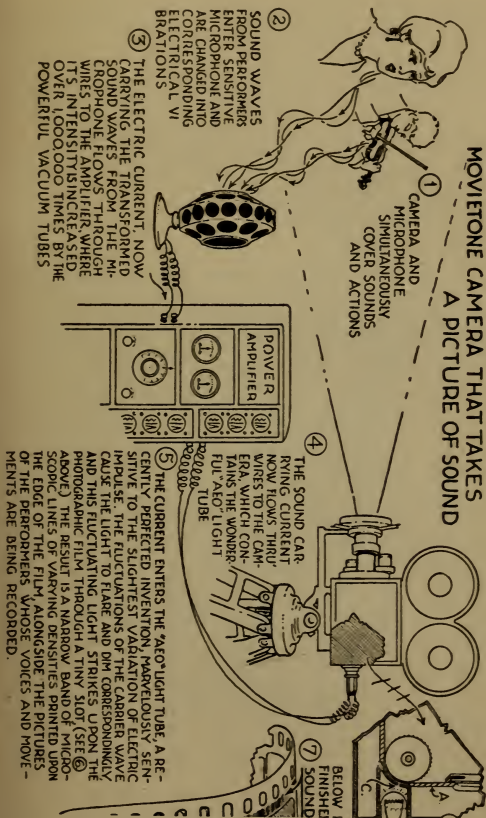
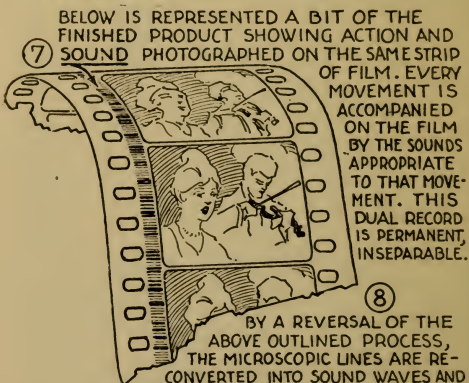
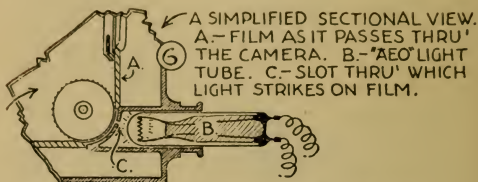


Fig. 12



BY A REVERSAL OF THE ABOVE OUTLINED PROCESS, THE MICROSCOPIC LINES ARE RE-CONVERTED INTO SOUND WAVES AND PROJECTED THROUGH A LOUD SPEAKER SIMULTANEOUSLY WITH THE PICTURE SHOWN UPON THE SCREEN. REPRODUCTION IS ABSOLUTELY AND AUTOMATICALLY SYNCHRONOUS.

Fig. 13

Upon leaving college Mr. Case started work for the purpose of discovering substances which are sensitive to light, and which will respond quickly and accurately, eliminating the inertia which is common in change of resistance materials like selenium.

After spending about five years on the development of photo-electric cells, about ten different materials were found to be especially sensitive to light, and two of these materials, namely, thalofide cell and the barium cell (photo-electric), were outstanding in their characteristics to serve as tools in the solution of the problem requiring light cells. This work together with the work during the war, done by the Case Research Laboratory, on special signalling systems, led to the beginning of the development of a practical talking moving picture system.

The operation of the system is briefly as follows:

The sound is picked up by a high quality microphone. At present using the condenser transmitter developed by the Western Electric Co. After amplifying through four stages of amplification, the amplified sound is impressed upon a special light known as the "aeo" light. This light has the property of being very actinic and will respond accurately to impressed electrical variations. This accuracy of response is due to the incorporation of alkaline earth oxides on the cathode.

This aeo light constitutes one of the developments of the Case Research Laboratory. Previous to this attempts had been made to record sound using a gas discharge device maintained luminous on a high frequency discharge. This arrangement however, was un-



Fig. 14

Section of Fox Case Movietone Studios at 460 West 54th Street, New York City, which shows three Movietone cameras and other mechanical apparatus employed in the production of Movietone pictures.

satisfactory in that it did not give sufficient light and could not be modulated correctly.

In the Movietone system, the picture and sound are taken in the same camera. The sound is applied to the film at the point where the film is in contact with the feed sprocket. In this camera, precision gears have been installed between the shutter shaft and the sprocket shaft. The sprocket itself has been cut to an accuracy of better than .0001" in eccentricity. With this precision working, it is possible to obtain the uniform velocity of film necessary for accurate recording. The sound is applied to the film at a point adjacent to the sprocket holes and cutting of approximately $1/10''$ from the picture. The sound is printed at this point through a slit or aperture $1/10''$ long and .0008 $/10''$ wide.

The design of the sound aperture or slit is one of the big factors in the success of this system. Previously the sound has been recorded through slits formed by metal jaws. In this case trouble was experienced with the slits filling up with dust and dirt. Further, it was impossible to machine the slits sufficiently accurate to obtain good recording, even though the film was held in intimate contact with the slit. In the Movietone system the slit is produced by ruling an aperture on a piece of silvered quartz. A cover glass is then cemented to this quartz piece and this cover glass polished down to approximately 1000th of an inch in thickness. Under these conditions the film is not touching the slit, but due to the lense effect of the quartz, practically no spread in the light is experienced. The cover glass of course, solves the problem of the aperture becoming closed due to dirt or dust.

The camera is driven by a synchrononous motor and in this way it is possible to use as many cameras as necessary on a shot, without having trouble with the synchronism. In designing the camera we have been very careful to keep the thing entirely practical and noiseless. In the camera the distance from the centre of the picture to the corresponding sound below the picture is $7\frac{3}{4}$ ". The film is developed in the usual manner, preferably in a slow working developer. At present printing is done in a continuous printer, running through once for the sound and once for the picture exposure. The printer prints the picture with reference to the sound so that on the positive the difference between the picture and corresponding sound is $14\frac{1}{2}$ ".

The attachment for the projector for reproducing the sound film was designed to apply to the standard machines. It is applied below the head by fastening to the main casting and dropping down the take-up magazine. This attachment consists essentially of an accurate sprocket in a shaft with a large fly-wheel to give uniform velocity to the film. A 25 Watt straight coil filament lamp, fed by means of a high quality lens system upon one of the special slits, similar to the one described above and used in the camera. As the sound waves pass the slit they cause variations in the light. These variations fall upon a barium photo-electric cell which change the light variations into electrical variations. These electrical variations are amplified and come out as sound through the loud speakers placed at the screen.

This barium photo-electric cell is the only one that we have found which is sufficiently

fast in its response, sufficiently sensitive and sufficiently stable to be practical for this purpose.

In the Movietone system the loud speakers are placed behind the screen so that the illusion is perfect and it is impossible to localize the source of the sound. In order to be able to do this a special screen was developed which has sufficient reflective power to give a good picture and still is perfectly transparent to sound, due to oblique openings in the material of the screen.

The Movietone pictures are made in New York, at the Fox-Case Studios. These studios are of special construction and are said to embody the finest engineering practice of today from the standpoint of acoustical conditions, ventilation and adaptability to the purpose for which they are built. There are two rooms or studio stages in which production can go on either separately or simultaneously as necessary. Both studios are simple in size to allow for elaborate settings or large orchestral accompaniment; both studios have the usual equipment of lights used in motion picture production as well as the special apparatus required by the Movietone process.

The walls of these rooms are absolutely sound proof, so that it is never possible for outside noises to penetrate either room while a picture is being taken. In order to insure this complete isolation, each of the studios is wholly enclosed within a double wall. These walls are slightly over one foot in thickness, including an interior air space of six inches. Either side of this air space are three-inch walls of gypsum blocks and to the outside of each of these layers is an additional thick-

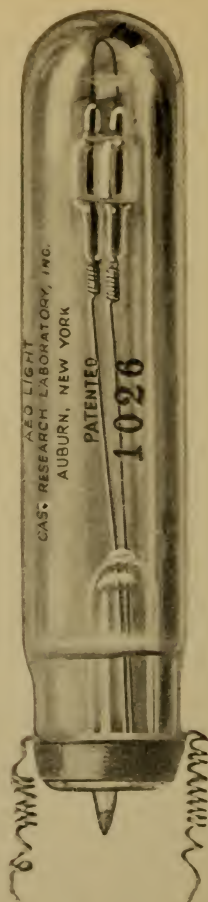


Fig. 15

ness of a patented material of cellular texture. On the inside of the studio walls this material is covered with heavy draperies of a sound-absorbing nature. Other similar draperies are hung about the studios. By this means, perfect acoustic conditions have been obtained.

Fig. 15 shows the AEO light, a patented product of the Case Research Laboratory, used exclusively in the Movietone process. From this tube comes the light which, photographed upon the film, is re-translated during the process of reproduction into the sound waves heard in the auditorium.

The air in these rooms is changed every three minutes, purified by a washing process, heated in the winter, refrigerated in the summer, so that a constant temperature is always maintained.

Aside from the fact that absolute silence is enjoined on all present, the production of a Movietone picture does not greatly differ from the ordinary motion picture production of a similar subject. The settings are constructed and lighted in the same way. A rehearsal is held before the actual picture-taking is made such as is often done in ordinary picture-making. While the action in a Movietone rehearsal is being checked up by the director sitting behind the camera, in another room the vocal director checks up the tonal quality through the simple device of a loud speaker connected with a microphone in the studio.

Aside from the fact that the camera is motor driven and that it is connected by wire with the telephonic apparatus, there is little dif-

ference between the recording of picture and voice by a Movietone camera and the ordinary picture recording in a motion picture studio.

In the Movietone process standard motion picture film is employed. On this film is recorded both the moving picture and its sound accompaniment, whether the latter be vocal or instrumental. In its basic elements the process is simplicity itself. It consists, briefly, in photographing variations in light intensity on moving picture film. This is accomplished by collecting the sounds to be recorded through the use of a microphone, which has the property of changing sound variations into electrical variations. These electrical variations are amplified, and in turn vary the intensity of the recording light. This recording, or "AEO" light, so called because of an alkaline earth oxide deposit on the filament, is high in actinic values.

It is contained in a glass tube which is inserted in the back of the camera in such a manner that the variations in light intensity fall directly upon a narrow edge of the negative film on which the motion picture is also simultaneously being recorded.

The presentation of a Movietone subject to the audience in the theatre or auditorium is in effect a reversal of this process. The standard film, containing both picture and sound in a photographic record, is run through a standard moving picture projection machine, to which has been attached a sound reproducing unit. This sound reproducing unit includes a light which is focused by a lense system through a narrow slit into the sound record of the film. As the sound record on the film passes by the slit, it interrupts the

constant light shining through it, and sets up light variations corresponding directly to those photographed. These changes in light variation then fall on a photo-electric cell, which changes the light variations back to electrical variations. These electrical variations are then amplified and carried by wire from the projection booth to the screen and reproduced on the screen through loud-speakers.

The process employed in making Movietone pictures is claimed by Fox Case Corporation as its individual process. It is the result of many years of experimentation and study conducted by the Case Research Laboratories in Auburn, N. Y. It was here that, under the direction of Theodore W. Case, was evolved the direct method of photographing sound waves on a strip of motion picture film employed in the Movietone process. The Case Laboratories, in this work, claim to have built up a strong chain of patents covering the crucial points of each step in their process. These patents have been filed in all of the principal countries in the world. It was the acquisition of these patents together with the knowledge and facilities of the Case Laboratories which led William Fox to affiliate himself in the formation of Fox Case Corporation. This combination of the Fox expert picture-making skill with the technical knowledge and process patents of the Case Laboratories resulted in the perfection of the Movietone process.

In the Fox Case process, aside from its own various particular patents, such, for instance as the "aeo" tube, certain telephonic apparatus is necessary. This embraces the use of such devices as amplifiers, microphones, loud

STANDARD PROJECTOR MOVIETONE ATTACHED TO A

MOVIETONE film A, from the magazine at the top, passes before the projecting lens, then down through the regulating sprockets and rollers enters MOVIETONE chamber at B.

Upon the edge of MOVIETONE film is a band of tiny horizontal lines—photographed sound waves. This band passes before a minute slot through which shines a powerful ray of light.

The ray is caused to fluctuate rapidly, according to the variable density of the “sound band” and enters the photo-electric cell C. Here the light vibrations are impressed upon an electric current which in turn actuates the detector tube D. From the tube the current goes to a multitube amplifier then enters the loud speaker, the whole resulting in perfect and simultaneous reproduction of picture and sound.

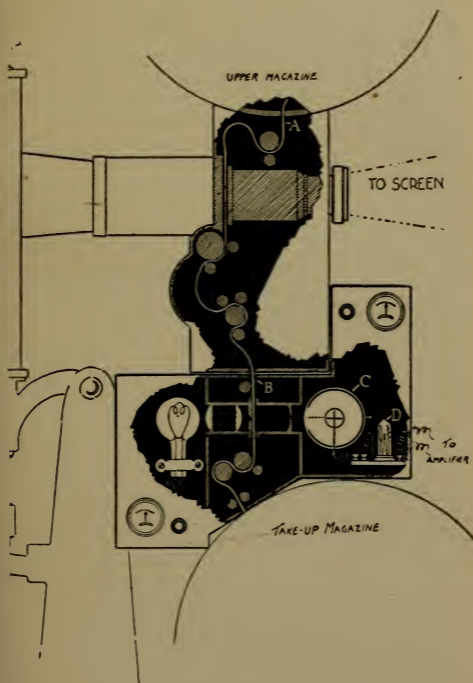


Fig. 17

speakers, both in recording and reproducing. Wherever telephonic apparatus is employed by Movietone the devices of the Western Electric Company are used. These are the devices which were acquired by Vitaphone under an exclusive license from Western Electric, and the use of which by Movietone is covered by an agreement between Fox Case Corporation and The Vitaphone Corporation. Since the telephonic equipment, which is the principal part of an installation, is common to both Vitaphone and Movietone, reproducing attachments for these two systems are now being so designed that both can be put on the one projection machine. This enables the exhibitor, after having secured installation, to reproduce both Vitaphone and Movietone pictures at will over the same machines.

Fig. 16 shows movietone camera and recording apparatus, in the Fox Case Studios, New York City.

Many advantages are claimed by the Fox Case people for the Movietone process. Of first importance, it is pointed out, is the fact that the sound and the picture are contained on the same strip of film, so that it is never possible for them to become separated. Neither is it possible for sound and picture to get out of synchronization. Thus it is not necessary for the operator to start the picture at any one spot. In case of film breaks, where it is necessary to cut out one or more frames in order to splice the film together, there is always a loss of the same amount of sound as there is of picture, so that this in no way disturbs synchronization.

The inclusion of the sound on the strip of standard film means that no extra cost or difficulty in handling is experienced in shipment of Movietone shows. In fact, these films can be handled in all respects the same as ordinary picture film.

An advantage seen in the recording process comes from the fact that Movietone recording cameras are an adaptation of a standard motion picture camera, motor driven, and can be handled with the same facility as the ordinary camera. There are no unusual restrictions in the handling of this recording equipment, and it can thus be placed for any desirable shots, and changed from distance to close-up range at will.

THE VITAPHONE

The Warner Bros. VITAPHONE was one of the first systems to meet with public approval, this is the system where the sound is recorded onto a wax disc in much the same manner that sound is now recorded on victrola records.

The Vitaphone productions are being made in New York City, and Mr. E. B. Du Par A. S. C. is responsible for the camera end of the productions, and is also responsible for the following description of how the pictures are made:

One of the things, that has made Vitaphone possible was the 'synchronus' motor. Instead of using one motor and driving the camera and the recording machine from opposite ends, which at first was thought to be the simplest way, we now have from two to four motors all going at the same time and electrically interlocked so that they are all in perfect synchronization. An electrical gearing device holds them at exactly the same speed. The motors are interlocked electrically by tapping at three symmetrical points on each armature and by interconnecting the different motors through slip rings. Thus the motor driving the recording machine and the motors driving the different cameras are independently supplied with electrical energy, but through the slip ring circuit there is enough interchange of power between their armatures to produce synchronization. While starting and when they reach the desired speed they are converted into synchronous motors and continue to run as independent synchronous motors, the speed being determined by the frequency of the power supply which can't

vary one-tenth of one per cent.

One of the first problems, which I had to overcome was to cut down the camera noise. By putting a special clutch on the magazine take-up changing the intermittent movement in the camera, using a special belt and shooting from a sound-proof camera booth, the operation of the camera was made so quiet that you could get within ten feet of the microphone, where before it was impossible to get closer than 25 feet.

"The next problem was to get the light quiet enough to work with. After a number of experiments and tests,, I decided to use the G. E. high intensity arc light in conjunction with special spot lights and Cooper Hewitts. But before they could be used at all, they had to be re-made with all gears and moving parts constructed of fiber. It is a very severe test that these lights have to undergo. They have to burn from 11 to 15 minutes at a time and be absolutely noiseless, because a little flicker of the arc or carbon sounds like a pistol shot on the finished record.

The reason of course, that we need the noiseless lights is because the microphone is so sensitive that everything has to be absolutely quiet while photographing, as the recording machine gathers the different sounds by a special microphone which translates them into voltage fluctuations--the vibrations caused by the sounds striking the diaphragm. The minute fluctuations are in turn amplified by a vacuum tube amplifier until they have sufficient power to operate the device or stylus which cuts the minute lines in the record of soft wax. This wax is 16 inches across, and runs for approximately 11 minutes, or equal to 1,000 ft. of film

when projected at the speed of 90 feet per minute. Incidentally, that is the speed at which we have to take pictures with our camera—24 pictures per second, which is one-half again as fast as the natural speed of 16 pictures per second.

We have from two to four cameras going at one time. The long-shot camera, is what we call the master camera. It takes the master film and is interlocked with the recording machine. Once it starts, it keeps going till the end. The close-up camera, has a synchronous motor and can be started and stopped at will. I have taken as many as ten close-ups during one number, or in the space of 11 minutes. I have four lenses on the camera, ranging from a 40 mm. to a six-inch. They are all focused in advance. All I have to do is to change them, and panoram the camera to the next object to be photographed.

The noise incident to the taking of a motion picture made it necessary to shut the camera in a special sound-proof booth. With the camera, I was locked in the booth. I shot through a small aperture, and looked out through a small peek hole. However, the construction of the booth does not permit of the booth's occupant to hear anything from without. It is necessary to depend entirely on light signals for starts and fades.

"The camera is run by a motor which is synchronized with the recording motor. Instead of running at the regular speed of 16 pictures per second, we exposed at the rate of 24 per second. The recording machine is so located that it is in another part of the building, far enough away so that no sound can get to the actual place of photographing.

The apparatus in the recording room is in charge of a recording expert. Another expert is stationed at the 'mixing panel,' as we call it, his duties being to listen to what is being recorded and also to watch a very sensitive dial that indicates every little variation of sound. When the dial starts to jump up to a certain mark, he has to vary the amplification on the microphone so as not to cut over certain high notes; high frequencies are apt to make the cutting point on the record break through the delicate walls of wax and spoil the record.

"The master recorder," Du Par continues, "was stationed on the sixth floor above. us

"He is surrounded by dials whereby he can tell just what the vocal actions of the artists are. He is also attended by a large horn, about five feet square, in which he listens for any foreign noises. The microphones are so sensitive that he can detect if anybody on the set makes the least noise, such as walking, whispering or even the flickering of a light. If such are recorded, then the record is ruined.

"When reproducing, the film and the record are placed in their respective machines with a given mark indicating the starting point. They are coupled to opposite ends of the same motor, the speed of which is held constant by means of a vacuum tube regulator. It is essential that the mechanical gearing be so designed that mechanical vibrations and irregularities of load in the projector should not cause fluctuations in the speed of the record or film. To avoid this, a flywheel and 'flexible connection are placed between the last gear-driven shaft and the turntable, which iron out the ripples in the speed.

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"The sound is brought to the audience by an electrical reproducer that converts the delicate movements of the needle in the grooves of the disc into electrical vibrations—which pass through an adaptation of the Western Electrical public address system.

GLOSSARY OF ELECTRICAL AND MECHANICAL TERMS

ACETATE. A salt formed by the action of acetic acid upon a base.

ACTUAL HORSE POWER. The exact useful power given out by an engine: found by subtracting the power used by the machine itself from the indicated horse power.

ACROMATIC LENSES. The color effect caused by the chromatic aberration of a simple lens greatly impairs its usefulness. This may be overcome by combining into one lens a concave lens of flint glass and a convex lens of crown glass.

ALIGN. To place or form in line.

ALLOY. A mixture of two or more metals.

ALTERNATING CURRENT. A current that changes its flow of direction so many times a second according to the construction of the alternator. Written A. C.

AMMETER. An instrument used to measure the flow of amperes.

AMPERE. The unit of current strength.

AMPERE HOUR. The quantity of electricity passed by a current of one ampere in one hour.

One ampere flowing for one hour.

Two amperes flowing for one-half hour.

One-half ampere flowing for two hours: all equal one ampere hour.

ANCHOR BOLTS. Bolts used for fastening machines to their foundation.

ANTI-FRICTION METAL. A tin-lead alloy like Babbitt metal.

APERTURE. An opening of any description in a partition.

ARC. The arc between two carbon electrodes slightly separated.

ARC RECTIFIER. An apparatus used to change A. C. to D. C.

ARMATURE. A collection of pieces of iron designed to be acted on by a magnet.

ASBESTOS. A fibrous variety of ferro-magnesium silicate; is a non-conductor of heat and fireproof.

ASBESTOS COVERED WIRE. A cable containing very fine strands of copper wire all twisted together and covered with an asbestos covering. Used wherever heat is generated. On motion picture circuits used between the table switch and arc lamp.

AUTOMATIC. Self-acting.

AUTOMATIC SHUTTER. The shutter covering the film aperture in gate of machine and controlled by the centrifugal or governor movement, is so arranged that the shutter will remain up so long as the machine is in motion, but should the machine stop for any reason then the shutter falls and cuts off the rays of light from the film in gate. (A fire prevention device.)

AUTO TRANSFORMER. A transformer provided with only one coil instead of two. Part of the coil being traversed by the primary circuit and part being traversed by the secondary circuit.

B. S. W. G. Abbreviation for Brown & Sharpe Wire Gauge.

B. W. G. Abbreviation for Birmingham Wire Gauge.

B. X. Metal tubing containing two conductors, each conductor insulated from the other by a rubber covering, and both wires wrapped with a composition covering so as to completely fill the tubing.

BABBITT METAL. An anti-friction metal.

BACK FOCUS. Properly called working distance.

BACK FOCACL LENGTH OF LENS. The distance from the back of the lens to the film in the gate, while the film image is in focus on the screen.

BALANCE WHEEL. A fly wheel. A wheel added to machinery for the purpose of preventing too sudden variations in speed.

BALL AND SOCKET JOINT. A joint in which a spherical object is placed within a socket made to fit it.

BALL BEARING. A bearing whose journal works upon a number of metal balls. Used to reduce friction to a minimum.

BED PIECE. The frame carrying the dynamo or motor.

BORE. The interior diameter of a cylinder.

BRUSH. A rod of carbon held in a holder and pressed against the commutator.

BUSINESS. Action by the player; e. g., business of shutting door.

BUST. A small, magnified part of a large scene.

CABLE. An insulated electric conductor.

CAM FRICTION. The friction existing between the cam and the member connected to it.

CAMERA. An expression used to command the photographer to begin taking the scene.

CANADA BALSAM. A gum obtained from the Balsam Fir of Canada. Used for cementing lenses.

CARBON. One of the elements, exists in three forms, charcoal, graphite and diamond. It is used as electric conductor for arc lamps and incandescent lamp filaments. The carbons used for arc lamps generally have a central core of soft carbon.

CARRYING CAPACITY. The capacity of an electrical conductor to carry current without overheating.

CENTIMETER. Unit of length, 0.3937 inch.

CENTRIFUGAL FORCE. The force which draws a body constrained to move in a circular path, away from the center of rotation.

CHANGE OVER. The stopping of one projecting machine and the simultaneous starting of a second machine in order to maintain an uninterrupted picture on the screen when showing a multiple-reel story.

CHECK NUT, generally called lock-nut. A nut placed over another nut on same bolt to lock the main nut in place.

CHROMATIC ABERRATION. When white light is passed through a spherical lens, both refraction and dispersion (the decomposition of white light into several kinds of light) occur. This causes a separation of the white light into the various colors and causes images to have colored edges. This effect which is most observable in condenser lenses is due to the unequal refrangibility of the simple colors.

CINE. A prefix used in description of the motion-picture art or apparatus.

- CIRCUIT.** The path through which the electric current flows.
- CIRCUIT BREAKER.** Any apparatus for opening or closing a circuit.
- CIRCUIT-CLOSED.** A circuit closed so as to give the current a continuous path.
- CIRCUIT, OPEN.** A circuit with its continuity broken, as by the opening of a switch.
- CLOSE-UP.** Scene or action taken with the character close to the camera.
- COLLODION.** A solution of pyroxylin (soluble gun cotton) in ether. Used in film cement.
- COMMUTATOR.** That part of a dynamo that changes the direction of the currents.
- COOLING PLATE.** The plate around the film aperture on gate which protects the gate itself from getting overheated from the rays of light from arc lamp.
- CONDUCTOR.** Anything that will permit the passage of electricity. A wire.
- CONDENSERS.** A lens or set of lenses used to gather the rays of light from the arc lamp and bring them to a fixed point of focus on aperture in gate.
The lens combination which deflects the diverging rays of the luminant into the objective.
- Collector Lens.* The lens next to the source of light.
- Converging Lens.* The lens nearest the objective.
- Middle Lens.* Of a three-lens combination, the lens lying between the collector lens and the converging lens.
- CONDUIT.** A metal pipe through which electrical conductors are run.

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CONTACT, ELECTRIC. A contact between two conductors giving a continuous path for the current.

CONSTANT LOAD. A load whose pressure is steady and invariable.

CONTINUOUS. Uninterrupted without break, or interruption.

CONVERTER. An electric machine or apparatus for changing the potential difference of an electrical circuit.

CORROSION. Chemical action which causes destruction of a metal, usually by oxidation or rusting.

CORRUGATED. Formed with a surface consisting of alternate valleys and ridges.

COULOMB. The practical unit of quantity of electricity. It is the quantity passed by a current of one ampere intensity in one second.

CRATER. The depression that forms in the positive carbon of a voltaic arc.

CURRENT FREQUENCY. The number of times alternating current changes its flow of direction a second. The changes are called cycles.

CUT-BACK. Scenes which are returns to previous action.

CUT-IN. Anything inserted in a scene which breaks its continuity.

CUTTING. Editing a picture by elimination of useless or unacceptable film.

DEVELOPING. Making visible the latent image in an exposed film.

DIRECT CURRENT. A current that flows in the one direction. Written D. C.

DIMMER. An adjustable choking coil used to

regulate the intensity of electric incandescent lamps.

DIRECTOR. The person who directs the actual production of the photoplay.

DISSOLVE. The gradual transition of one scene into another.

DOUBLE EXPOSURE. The exposure of a negative film in a camera twice before development.

DOUBLE PRINTING. The exposure of a sensitive film under two negatives prior to development.

DOUSER. The manually operated door in the projecting machine which intercepts the light before it reaches the film.

DUPE. A negative made from a positive.

DUPLEX. Double; working in two ways at once.

DYNAMOS. A machine driven by power used to convert mechanical energy into electrical energy.

E. M. F. Abbreviation for electric-motive force.

ECONOMIZER. A step-down transformer.

EFFECTIVE APERTURE. The largest diameter of a lens available under the conditions considered.

ELECTRICITY. An unknown power; a powerful physical agent which manifests itself mainly by attraction and repulsions, also by luminous and heating effects, by violent commotions, by chemical decompositions and many other phenomena.

ELECTRODE. The terminal of an open electric circuit.

EQUIVALENT FOCUS. The distance from a point half way between the back and front com-

bination of lenses to the film in the gate while picture is in focus on screen.

Can be obtained by measuring the distance between the front and back combination then dividing by two and adding the result to the back focal length. (Written E. F.)

The equivalent focus of a plurality of lenses in combination is the focal length of a simple thin lens which will under all conditions form an image having the same magnification as will the given lens combination.

EXHAUST FAN. An air propeller used to create a vacuum.

EXTERIOR. A scene supposed to be taken out of doors.

FADE-IN. The gradual appearance of the picture from darkness to full screen brilliancy.

FADE-OUT. The gradual disappearance of the screen-picture into blackness. (The reverse of fade-in.)

FEATURE. A pictured story, a plurality of reels in length.

FIRE TRAP. An arrangement of rollers on the upper and lower magazines through which the film is fed, used to prevent the flame, in case of fire, from entering the magazines.

FIXING. Making premanent the developed image in a film.

FLAT. A bit of painted canvas, or the like.

FLASH. A short scene, usually not more than three to five feet of film.

FLASH-BACK. A very short cut-back.

FOCAL. Pertaining or belonging to a focus.

FOCUS. The point of concentration. When rays reflected from all points meet or concur.

- FOOTAGE.** Film length measured in feet.
- FLICKER SHUTTER.** A revolving shutter on head of machine just in front of the projection lens, its use being to cut off the rays of light from screen while the film is in motion in gate.
- FRAME (verb.)** To bring a frame into register with the aperture during the period of rest.
- FRAME (noun).** A single picture of the series on a motion-picture film.
- FRAME LINE.** The dividing line between two frames.
- FRAMING DEVICE.** An attachment on the machine which allows the operator to frame the picture on screen.
- FUSE.** A short length of wire of a given fusible point introduced into the electrical circuit.
- FUSING POINT.** The temperature at which metals melt and become liquid.
- GENERATOR.** An apparatus for maintaining an electrical current.
- GOVERNOR MOVEMENT.** The movement that works the automatic shutter, works by centrifugal force.
- GRAPHITE.** A soft form of carbon, used as a lubricant.
- GROUND.** The contact of an electrical conductor with the earth, or with some other conductor not in the circuit.
- HORSE POWER.** A unit of rate of work. Equal to the raising of 33,000 pounds,, one foot in one minute; equal to 746 watts.
- INDUCTION.** The property of a charged body

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on A. C. to charge a neighboring body running parallel to it without any tangible form of connection.

INDUCTOR. A step-down transformer.

IMPEDANCE. Is to an A. C. circuit what resistance is to a D. C. circuit.

INSULATING TAPE. A prepared tape to cover the ends of bared wire.

INTERMITTENT MOVEMENT. The movement that drives the intermittent sprocket, generally a four-to-one movement.

INTERMITTENT SPROCKET. The sprocket which engages the film to give it intermittent movement at the picture aperture.

INSERT. Any photographic matter, without action, in the film.

INTERIOR. Any scene supposed to be taken inside a building.

IRIS. An adjustable lens diaphragm.

IRISING. Gradually narrowing the field of vision by a mechanical device on the camera.

JOINING. Splicing into a continuous strip (usually 1,000 feet) the separate scenes, titles, etc., of a picture.

KILOWATT. Equal to 1,000 watts.

LAMINATED. Made up of a number of thin sheets.

LANTERN PICTURE. A still picture projected on screen by means of an optical lantern or stereopticon.

LANTERN SLIDE (see slide). The transparent picture from which a lantern picture is projected.

LEADERS. That piece of blank film attached to the beginning of the picture series.

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LENS. A lens may be defined as a piece of glass or other transparent substance with one or both sides curved. Both sides may be curved, or one curved and other flat.

The object of the lens is to change the direction of rays of light and thus magnify objects or otherwise modify vision.

Lenses may be classed as:

Double convex

Plano convex

concavo convex

Double concave

Plano concave

Convexo concave

The focus of a lens is the point where the refracted rays meet.

LIGHT BEAM. A bundle of light rays.

LIGHT RAY. A thin line of light.

LOCATION. Any place selected for the action of an outdoor scene.

LOST MOTION. Motion in a part of machine that produces no useful results.

LUBRICANT. An oil used to diminish friction in the working parts of machinery.

LUG. A wire terminal.

MAGAZINE VALVE. The film opening in the magazine of a motion-picture projector.

MAN POWER. Equal to one-tenth of a horse power.

MASKS. Opaque plates of various sizes and shapes used in the camera to protect parts of the negative from exposure.

MICA. A mineral more or less transparent and used for insulating.

MIL. Unit of length.

MIL, CIRCULAR. Unit of area.

TALKING MOVIES

MOTION-PICTURE. The synthesis of a series of related picture elements, usually of an object in motion.

MOTION-PICTURE FILM. The ribbon upon which the series of related picture elements is recorded.

MOTION-PICTURE PROJECTOR. An optical lantern equipped with mechanisms for suitably moving motion-picture film across the projected light.

MOTOR GENERATOR. A motor connected to a generator.

MOTOR REGULATOR. An adjustable rheostat used to regulate the speed of the motor.

MOVIES. Motion-pictures.

MULTIPLE. Multiple connection is when each lamp draws its supply direct from the main and is not depending on any other lamp or set of lamps for supply.

MULTIPLE-REEL. A photoplay of more than a thousand feet of film in length.

NEGATIVE. The opposite to positive; the pole to which the current is supposed to flow.

NEGATIVE. The developed film, after being exposed in a camera.

NEGATIVE STOCK. Light sensitive film intended for motion-picture camera use.

NON-CONDUCTOR. Any material that does not conduct electricity.

OBJECTIVE. The picture-forming member (lens) of the optical system. The objective lens of a moving picture machine generally consists of four lenses, two in the front combination and two in the rear. The two lenses in the front are cemented together with Canada Balsam and called the compound

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lens. The back combination consists of two lenses separated by a metal ring, called the duplex lens.

The convex or greatest convex side of a lens always faces the screen.

OHM. The unit of electrical resistance.

OSCILLATION. A moving backward and forward; swinging like a pendulum.

OPTIENCE. A collection of persons assembled to see motion pictures.

PAM. Contraction for panorama.

PANORAMA. The act of, or devise for, turning a motion-picture camera horizontally, to photograph a moving object, or to embrace a wide angle of view.

PHOTOPLAY. A story in motion pictures.

POLARITY. Pertaining to the two opposite poles of a circuit; the positive and negative.

POLYPHASE. More than one phase, multiphase.

POSITIVE. The developed film, after being printed through a negative.

POSITIVE STOCK. The light-sensitive film intended to be printed upon through a negative.

PRE-RELEASE. A picture not yet released for public showing.

PRESSURE, ELECTRIC. Electric motive force, voltage.

PRIMARY COIL. The coil of a transformer, connected to the source of electrical supply.

PRIMARY COLORS. Red, yellow, blue.

PRIMARY POWERS. Water power, wind power, tide power, power of combustion, power of vital action.

- PRINT.** Same as "positive."
- PRODUCER.** The maker of photoplays.
- PROGRAM.** The complete show for a single performance.
- PROJECTION DISTANCE.** The distance between the screen and the objective of a stereopticon lantern or motion picture projecting machine.
- PROJECTING LENS.** Properly called projection objective.
- PROJECTION OBJECTIVE.** The objective which forms an image of the lantern slide or film, upon the screen.
- PROPS.** Contraction of properties. Objects used as accessories in a play.
- RACING OF MOTORS.** The rapid acceleration of speed of a motor when the load upon it is removed.
- REEL.** An arbitrary unit of linear measure for film—approximately a thousand feet.
- REEL.** The metal spool upon which the film is wound.
- REFLECTION.** The change of direction experienced by a ray of light when it strikes a surface and is thrown back or reflected. Light is reflected according to two laws.
- (a) The angle of reflection is equal to the angle of incidence.
 - (b) The incident and the reflected rays are both in the same plane which is perpendicular to the reflecting surface.
- REFRACTION.** The change of direction which a ray of light undergoes upon entering obliquely a medium of different density from that through which it has been passing. In this case the following laws obtain:

- (a) Light is refracted whenever it passes obliquely from one medium to another of different optical density.
- (b) The index of refraction for a given substance is a constant quantity whatever be the angle of incidence.
- (c) The refracted ray lies in the plane of the incident ray and the normal.
- (d) Light rays are bent toward the normal when they enter a more refracted medium and from the normal when they enter a less refracted medium.

REGISTER. A term denoting facial expression of emotions.

RELEASE. The publication of a photoplay.

RETAKE. Rephotographing a scene.

REWIND. The process of reversing the winding of a film, usually so that the end to be first projected shall lie on the outside of the roll.

REWINDER. The mechanism by which rewinding is accomplished.

RESISTANCE BOX. A box filled with resistance coils connected in series.

RHEOSTAT. An instrument used to offer resistance to the flow of current. Made of a number of metal coils connected in series and mounted on a frame.

RUBBER COVERED WIRE. A cable either solid or stranded with a rubber covering and an outer protective covering of cotton braid. Used for mains for motion picture work.

SCENE. The action taken at a single camera setting.

SCENARIO. A general description of the action of a proposed photoplay.

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SCREEN. The surface upon which a picture is optically projected.

SECONDARY COIL. The coil of a transformer in which the current is induced, connected to the lamp.

SERIES. An electrical connection where lamps are connected so that they depend on each other for supply, the current passing through each lamp successively.

SHOOTING A SCENE. Photographing the scene.

SHORT CIRCUIT. Two wires of opposite polarity coming in contact with each other, without any controlling device.

SHUTTER. The obscuring device, usually a revolving segmental disc, employed to intercept the light during the movement of the film in motion-picture apparatus.

Shutter—Working Blade (also variously known as the cutting blade, obscuring blade, main blade, master blade or travel blade). That segment which intercepts the light during the movement of the film at the picture aperture.

Shutter—Intercepting Blade (also known as the flicker blade). That segment which intercepts the light one or more times during the rest or projection period of the film to eliminate flicker.

SIXTY CYCLE A. C. This is when every part of the circuit is 60 times positive and 60 times negative every second. The current changes its flow of direction 60 times a second.

SINGLE PHASE. Using only two wires and one E. M. F., sometimes called monophase or uniphase.

SINGLE PICTURE CRANK (sometimes referred

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to as trick spindle). That spindle and crank on a motion-picture camera which makes one exposure at each complete revolution.

SLIDE (Stereo Slide). The transparent picture from which a screen still is projected.

SLIDING FRICTION. The friction existing between two bodies in sliding contact with each other.

SPEED REGULATOR. An attachment on machine (generally a friction disc arrangement) used to regulate the speed of machine (not the speed of motor).

SPHERICAL ABERRATION. The reflected rays of concave spherical mirrors do not meet exactly at the same point. This is called spherical aberration.

SPLICING. Joining the ends of film by cementing.

SPLIT REEL. A reel having two or more picture subjects thereon.

SPOT. The illuminated area on the aperture plate of a motion-picture projector.

SPROCKET. The revolvable toothed member which engages the perforations in the film.

STAGE CABLE. A cable containing twin conductors each insulated from the other and the whole thing covered with a composition covering. Used for temporary purposes.

STEP-DOWN TRANSFORMER. A transformer that steps down the voltage and raises the amperage.

STEP-UP TRANSFORMER. A transformer that steps up the voltage and lowers the amperage.

STEREOPTICON. A lantern for projecting transparent pictures, i. e., lantern slides, often a

double lantern for dissolving.

STILL. A picture from a single negative.

STRIKING THE ARC. The act of bringing the carbons of an arc lamp together, and immediately separating them, thus establishing the arc.

SWITCH BOARD. A board to which wires are led connecting with cross bars or switches.

SWITCH, DOUBLE POLE. A heavy switch which connects and disconnects two leads simultaneously.

SWITCH, KNIFE. A switch with knife-like blade used on circuits carrying high-amperage.

SWITCH, SNAP. A small switch made to give a sharp break used on home lighting circuits.

SWITCH, TPREE WAY. A switch so constructed that by turning its handle, connection can be made from one lead to either of two other leads, and also so that connection can be completely cut off.

TAKE-UP (noun). The mechanism which receives and winds the film after it passes the picture aperture. Generally consists of a split pulley and tension spring, its use is to drive and control the speed and tension of the reel taking up the film in lower magazine.

TAKE-UP (verb). Winding up the film after it passes the picture aperture.

TENSION SPRINGS. On gate of machine, used to give the proper tension to film while passing aperture.

THREE WIRE SYSTEM. A system of distribution of electric current where three wires instead of two sets of two wires are used.

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The middle or neutral wire acts as positive wire for the negative, and as negative wire for the positive. The advantage of the system is the saving of copper.

THREE PHASE. A system of electrical distribution making use of three separate currents. These currents may be super-imposed, and generally only three wires are used in this transmission.

THROW. Projection distance. Distance from front combination of lens to screen.

TILT. The act of, or device for, moving a camera vertically while in use.

TINTING. Coloring a film by dyeing the gelatine side of it.

TONING. Coloring a film by chemical action on the silver image.

TRAILER. That piece of blank film attached to the end of a picture series.

TRANSFORMER. An apparatus used on alternating current systems to raise or lower the voltage.

TRANSFORMER. A motor generator set, an A. C. motor connected to a D. C. generator.

TRICK CRANK. A camera crank giving a single exposure for each turn.

TRICK-PICTURE. A picture in which unnatural action appears.

TWO PHASE. An A. C. system of electrical distribution making use of two currents of different phase. Can be arranged with either 3 or 4 wires.

VISION. A new subject introduced into the main picture, by the gradual fading-in and fading-out of the new subject, as, for example, to visualize a thought.

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VOLTAGE. Electric motive force or pressure.

VOLTMETER. An instrument used to measure the electric pressure.

WATT. The practical unit of electrical power. Equal to amperes times volts.

WATT HOUR. Amount of watts times length of hours.

WORKING DISTANCE. The distance from the principal focus of a lens to its nearest face; e. g., the distance from the slide or film to the nearest lens of the objective.

MOTION PICTURE STANDARDS

The following have been adopted as standards by the Society of Motion-Picture Engineers, and are promulgated to encourage uniformity and standard practice throughout the Industry as a whole. Their early universal adoption will save the industry a great deal of present annoyance and monetary loss.

FILM SPEED. A film movement of sixty feet per minute through motion-picture mechanisms shall be considered as standard speed.

FRAME LINE. The dividing line between pictures on motion-picture film shall be exactly midway between the marginal perforations.

INTERMITTENT GEAR RATIO. The movement of the intermittent gear shall be expressed in degrees of rotation during which the pin of the driver is in contact with the slot of the driven gear. For example, a gear in which the pin is engaged with the slot for one-quarter of a revolution of the driver shall be called a 90-degree movement; that in which the pin is engaged with the slot for one-sixth of a revolution shall be called a 60-degree movement, etc.

LANTERN SLIDE MAT OPENING. A standard opening in mats of lantern slides for use in conjunction with motion pictures shall be 3 inches wide by $2\frac{1}{4}$ inches high.

THUMB MARK. The thumb mark spot on a lantern slide shall be located in the lower left-hand corner next the reader when the slide is held so as to be read against a light.

LANTERN STRIP. A red binding strip to be used on the lower edge of the lantern slide.

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PICTURE APERTURE. The standard film picture aperture in a projecting machine shall be 0.906 inch wide and 0.6795 inch high, namely $29/32''$ and $87/128''$.

PROJECTION ANGLE. The maximum permissible angle in picture projection shall not exceed twelve degrees (12°) from a perpendicular to the screen surface.

PROJECTION LENS FOCI. The focus of motion-picture projection lenses shall increase in $1/4''$ steps to 8 inches and from 8 to 9 in $1/2''$ steps.

PROJECTION LENS MOUNTING. Picture projecting lenses shall be so mounted that the light from the film picture aperture shall have an uninterrupted full path to the rear component of the lens.

PROJECTING LENS HEIGHT. The standard height from the floor to the center of the projecting lens of a motion-picture machine shall be 48 inches.

PROJECTION LENS OPENING. The diameter of unit opening for projecting lens holder shall be $1\ 15/16$ inch.

PROJECTION OBJECTIVES. Shall have the equivalent focal length marked thereon in inches and quarters and halves of an inch, in decimals, with a plus (+) or minus (—) tolerance not to exceed 1% of the designated equivalent focal length also marked by the proper sign following the figure.

REEL. The approved standard reel shall be $10''$ in diameter; $1\ 1/2''$ inside width; with $5/16''$ center hole, with a key-way $1/8''$ by $1/8''$ extending all the way through; a 2" hub; and a permissible flange wobble of not more than $1/16''$.

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STANDARD PICTURE FILM. Shall be one and one-third inches wide and carry a picture for each four perforations, the vertical position of the picture being longitudinal of the film.

STANDARD REEL FILM. Shall have black film leaders, with tinted (red, green or blue) trailers; should have marking thereon embossed rather than punched in the film; and each reel of a multiple-reel story should end with a title, and the next reel begin with the same title.

TAKE-UP PULL. The take-up pull on film shall not exceed 15 ounces at the periphery of a 10-inch reel or 16 ounces on a (11-inch) reel.

TABLE SHOWING CARRYING CAPACITY OF WIRES: DISTANCE TO WHICH FULL LOAD MAY BE CARRIED AT 2 VOLTS DROP AND NUMBER OF LIGHTS EQUIVALENT TO FULL CURRENT GIVEN

B. & S. Gage	Rubber Insu- lation Amperes	Distance in Feet Causing a Loss of 2 Volts	Total Capacity in Watts		Total Number of Lamps of Different Voltages and Wattages that may be supplied									
					25-Watt		40-Watt		60-Watt		100-Watt		150-Watt	
			110 V.	220 V.	110 V. 220 V.	110 V. 220 V.	110 V. 220 V.	110 V. 220 V.	110 V. 220 V.	110 V. 220 V.	110 V. 220 V.	110 V. 220 V.	110 V. 220 V.	250-Watt
14	15	26	1650	3300	66	132	41	82	27	54	16	33	11	6
12	20	30	2200	4400	88	176	55	110	36	73	22	29	14	8
10	25	38	2750	5500	110	220	68	137	46	91	27	55	18	11
8	35	43	3850	7700	154	308	96	192	64	128	38	77	25	15
6	50	50	5500	11000	220	440	137	275	91	183	55	110	36	22
5	55	56	6050	12100	242	484	151	302	100	201	60	121	40	24
4	70	56	7700	15400	308	616	192	385	128	256	77	154	49	30
3	80	61	8800	17600	352	704	220	440	146	292	88	176	58	35
2	90	68	9900	19800	396	792	247	494	165	330	99	198	66	39
1	100	67	11000	22000	440	880	275	550	183	366	110	220	73	44
0	125	78	13750	27500	550	1100	343	686	220	458	137	274	91	55
00	150	82	16500	33000	660	1320	412	824	275	550	165	330	110	66
000	175	89	19250	38500	770	1540	481	962	320	640	192	384	128	77
0000	225	87	24750	49500	990	1980	618	1236	412	824	247	494	165	99
00000	200	92	22000	44000	880	1760	550	1100	367	734	220	440	146	88
300000	275	104	30250	60500	1210	2420	756	1512	504	1008	302	604	201	121
400000	325	114	35750	71500	1430	2860	893	1786	596	1192	357	714	238	143
500000	400	117	44000	88000	1760	3520	1100	2200	733	1466	440	880	293	176
600000	450	123	49500	99000	1980	3960	1237	2474	825	1650	495	990	330	198
700000	500	130	55000	110000	2200	4400	1375	2750	916	1832	550	1100	366	220
800000	530	135	60500	121000	2420	4840	1512	3024	1008	2016	605	1210	403	242

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LENS TABLE OF FILM PROJECTION

DISTANCE FROM FILM TO SCREEN

Stereo.	M. P.	15	20	25	30	35	40	45
8	2	5.04	6.74	8.44	10.14	11.84	13.54	15.24
		6.72	8.99	11.25	13.52	15.78	18.05	20.31
9	2½	4.48	5.99	7.50	9.01	10.52	12.03	13.54
		5.97	7.98	10.00	12.01	14.03	16.04	18.05
10	2½	4.02	5.38	6.74	8.10	9.46	10.82	12.18
		5.36	7.17	8.99	10.80	12.61	14.42	16.24
11	2¾	3.65	4.89	6.12	7.36	8.59	9.83	11.06
		4.87	6.52	8.17	9.18	11.46	13.11	14.76
12	3	3.34	4.47	5.61	6.74	7.87	9.00	10.14
		4.46	5.97	7.48	8.99	10.50	12.01	13.52
13	3¼	3.08	4.13	5.17	6.22	7.26	8.31	9.35
		4.11	5.50	6.90	8.19	9.69	11.08	12.48
14	3½	2.86	3.83	4.80	5.77	6.74	7.72	8.69
		3.81	5.10	6.40	7.69	8.99	10.28	11.58
15	3¾	2.66	3.57	4.47	5.38	6.28	7.19	8.10
		3.56	4.76	5.97	7.17	8.38	9.59	10.80
16	4	2.40	3.34	4.19	5.04	5.98	6.74	7.59
		3.32	4.45	5.59	6.72	7.85	8.98	10.12
17	4¼	2.34	3.14	3.94	4.74	5.54	6.34	7.14
		3.12	4.19	5.25	6.32	7.38	8.45	9.52
18	4½	2.21	2.97	3.72	4.48	5.23	5.99	6.74
		2.95	3.96	4.96	5.97	6.98	7.98	8.99
19	4¾	2.09	2.81	3.52	4.24	4.95	5.67	6.38
		2.79	3.74	4.70	5.65	6.61	7.56	8.51
20	5	1.98	2.66	3.34	4.02	4.70	5.38	6.06
		2.64	3.55	4.45	5.30	6.27	7.17	8.08
21	5¼	1.89	2.54	3.18	3.82	4.48	5.13	5.77
		2.51	3.37	4.24	5.10	5.96	6.83	7.69
22	5½	1.80	2.42	3.04	3.65	4.27	4.89	5.51
		2.40	3.22	4.05	4.87	5.70	6.52	7.34
23	5¾	1.72	2.31	2.90	3.49	4.08	4.67	5.27
		2.29	3.08	3.87	4.65	5.44	6.23	7.02
24	6	1.64	2.21	2.77	3.34	3.91	4.47	5.04
		2.19	2.95	3.70	4.46	5.21	5.97	6.72
25	6¼	1.57	2.11	2.66	3.20	3.75	4.29	4.83
		2.10	2.82	3.55	4.27	5.00	5.72	6.45
26	6½	1.51	2.03	2.56	3.08	3.60	4.12	4.65
		2.02	2.72	3.41	4.11	4.81	5.51	6.20
27	6¾	1.45	1.95	2.46	2.96	3.46	3.97	4.47
		1.94	2.61	3.28	3.95	4.63	5.30	5.97
28	7	1.40	1.89	2.37	2.86	3.34	3.83	4.31
		1.87	2.52	3.16	3.81	4.46	5.11	5.75
29	7¼	1.35	1.82	2.29	2.76	3.23	3.69	4.16
		1.80	2.42	3.05	3.67	4.30	4.92	5.69
30	7½	1.30	1.75	2.21	2.66	3.11	3.57	4.02
		1.74	2.34	2.95	3.55	4.16	4.76	5.37
31	7¾	1.26	1.70	2.14	2.58	3.01	3.45	3.89
		1.68	2.26	2.85	3.43	4.02	4.60	5.19
32	8	1.22	1.64	2.07	2.49	2.92	3.34	3.77
		1.62	2.19	2.75	3.32	3.89	4.45	5.02
33	8¼	1.18	1.59	2.00	2.42	2.83	3.24	3.66
		1.57	2.12	2.67	3.22	3.77	4.32	4.87
34	8½	1.14	1.54	1.94	2.34	2.74	3.14	3.54
		1.52	2.05	2.59	3.12	3.65	4.19	4.72
35	8¾	1.11	1.50	1.88	2.27	2.66	3.05	3.48
		1.48	2.00	2.51	3.03	3.55	4.06	4.58

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LENS TABLE OF FILM PROJECTION—Continued

DISTANCE FROM FILM TO SCREEN

Stero.	M. P.	50	56	60	64	70	76	80
8	2	16.93	18.97	20.33	21.69	23.73	25.77	27.13
		22.58	25.30	27.11	28.92	31.64	34.46	36.17
9	2½	15.06	16.87	18.07	19.28	21.09	22.91	24.12
		20.07	22.48	24.10	25.71	28.12	30.54	32.15
10	2½	13.54	15.17	16.26	17.34	18.98	20.61	21.70
		18.05	20.22	21.67	23.12	25.30	27.47	28.92
11	2¾	12.30	13.78	14.77	15.76	17.24	18.73	19.72
		16.40	18.38	19.70	21.01	22.99	24.97	26.29
12	3	11.27	12.63	13.54	14.44	15.80	17.16	18.07
		15.03	16.85	18.05	19.26	21.07	22.89	24.10
13	3¼	10.40	11.65	12.49	13.33	14.58	15.84	16.67
		13.87	15.54	16.66	17.77	19.45	21.12	22.23
14	3½	9.66	10.82	11.60	12.38	13.54	14.71	15.48
		12.87	14.43	15.46	16.50	18.05	19.60	20.64
15	3½	9.00	10.09	10.82	11.54	12.63	13.72	14.44
		12.00	13.46	14.42	15.39	16.84	18.29	19.26
16	4	8.44	9.46	10.14	10.82	11.84	12.86	13.54
		11.25	12.61	13.52	14.42	15.78	17.14	18.05
17	4¼	7.94	8.90	9.54	10.18	11.14	12.10	12.74
		10.58	11.86	12.72	13.57	14.85	16.13	16.98
18	4½	7.50	8.40	9.01	9.61	10.52	11.42	12.03
		9.10	11.21	12.01	12.82	14.03	15.23	16.04
19	4¾	7.10	7.96	8.53	9.10	9.96	10.82	11.39
		9.47	10.61	11.38	12.14	13.28	14.43	15.19
20	5	6.74	7.55	8.10	8.64	9.46	10.27	10.82
		8.98	10.07	10.80	11.52	12.62	13.70	14.42
21	5¼	6.42	7.20	7.72	8.23	9.01	9.79	10.30
		8.55	9.59	10.28	10.97	12.00	13.04	13.73
22	5½	6.13	6.87	7.36	7.86	8.60	9.34	9.83
		8.17	9.16	9.82	10.47	11.46	12.45	13.11
23	5¾	5.86	6.57	7.04	7.51	8.22	8.93	9.40
		7.81	8.75	9.38	10.01	10.96	11.90	12.53
24	6	5.60	6.28	6.74	7.19	7.87	8.55	9.00
		7.48	8.38	8.99	9.59	10.50	11.40	12.01
25	6¼	5.38	6.03	6.46	6.90	7.55	8.20	8.64
		7.17	8.04	8.62	9.20	10.07	10.94	11.52
26	6½	5.17	5.80	6.22	6.63	7.26	7.89	8.31
		6.90	7.74	8.39	8.85	9.69	10.53	11.08
27	6¾	4.98	5.58	5.98	6.38	6.99	7.59	8.00
		6.64	7.44	7.98	8.52	9.32	10.13	10.67
28	7	4.80	5.38	5.77	6.16	6.74	7.32	7.71
		6.40	7.18	7.70	8.21	8.99	9.77	10.28
29	7¼	4.63	5.19	5.57	5.94	6.51	7.07	7.41
		6.17	6.92	7.42	7.92	8.67	9.43	9.93
30	7½	4.47	5.02	5.38	5.74	6.28	6.83	7.19
		5.97	6.69	7.18	7.66	8.39	9.11	9.59
31	7¾	4.33	4.86	5.21	5.56	6.08	6.61	6.96
		5.77	6.48	6.95	7.42	8.12	8.82	9.29
32	8	4.19	4.70	5.04	5.38	5.89	6.40	6.74
		5.58	6.26	6.72	7.17	7.85	8.53	8.98
33	8¼	4.06	4.56	4.89	5.22	5.71	6.21	6.54
		5.41	6.07	6.51	6.95	7.61	8.27	8.71
34	8½	3.94	4.42	4.74	5.06	5.54	6.02	6.34
		5.25	5.89	6.32	6.74	7.38	8.02	8.41
35	8¾	3.82	4.29	4.60	4.91	5.38	5.84	6.15
		5.10	5.72	6.13	6.53	7.17	7.70	8.20

TALKING MOVIES

LENS TABLE OF FILM PROJECTION—Continued

DISTANCE FROM FILM TO SCREEN

Stero.	M. P.	84	90	96	100	104	110	116
8	2	28.49	30.53	32.57	33.93	35.29	37.33	39.34
		37.99	40.71	43.42	45.24	47.05	49.77	52.49
9	2¼	25.32	27.14	28.95	30.16	31.37	23.18	34.99
		33.76	36.18	38.60	40.21	41.82	44.24	46.55
10	2½	22.78	24.42	26.05	27.14	28.22	29.86	31.49
		30.37	32.55	34.72	36.17	37.62	39.80	41.97
11	2¾	20.70	22.19	23.67	24.66	25.65	27.13	28.61
		27.61	29.59	31.56	32.88	34.20	36.18	38.15
12	3	18.97	20.33	21.69	22.60	23.50	24.86	26.22
		25.30	27.12	28.93	30.14	31.35	33.16	34.97
13	3¼	17.51	18.77	20.02	20.86	21.69	22.95	24.20
		23.35	25.02	26.70	27.81	28.93	30.60	32.27
14	3½	16.26	17.43	18.59	19.37	20.14	21.31	22.47
		21.68	23.23	24.78	25.82	26.86	28.41	29.96
15	3¾	15.17	16.25	17.34	18.07	18.79	19.88	20.97
		20.22	21.67	23.12	24.09	25.06	26.51	27.96
16	4	14.22	15.24	16.25	16.93	17.61	18.63	19.65
		18.95	20.31	21.67	22.58	23.48	24.84	26.20
17	4¼	13.38	14.34	15.30	15.94	16.57	16.52	18.48
		17.83	19.11	20.39	21.25	22.10	23.38	24.66
18	4½	12.63	13.54	14.44	15.05	15.65	16.56	17.47
		16.85	18.05	19.26	20.07	20.87	22.06	23.29
19	4¾	11.96	12.82	13.68	14.25	14.83	15.86	16.54
		15.96	17.10	18.24	19.10	19.77	20.92	22.06
20	5	11.36	12.28	12.99	13.54	14.08	14.89	15.71
		15.15	16.23	17.32	18.05	18.77	19.86	20.95
21	5¼	10.82	11.60	12.38	12.89	13.41	14.19	14.96
		14.42	15.46	16.49	17.18	17.87	18.91	19.94
22	5½	10.33	11.07	11.81	12.31	12.80	13.54	14.28
		13.77	14.76	15.73	16.40	17.07	18.06	19.04
23	5¾	9.88	10.59	11.29	11.77	12.24	12.95	13.68
		13.16	14.11	15.06	15.69	16.32	17.26	18.21
24	6	9.46	10.14	10.82	11.27	11.72	12.40	13.08
		12.61	13.52	14.42	15.03	15.63	16.54	17.45
25	6¼	9.07	9.73	10.38	10.81	11.25	11.90	12.55
		2.10	12.97	13.84	14.42	15.00	15.87	16.74
26	6½	8.72	9.35	9.98	10.40	10.82	11.44	12.07
		11.64	12.48	13.31	13.87	14.43	15.27	16.10
27	6¾	8.40	9.00	9.60	10.01	10.41	11.02	11.62
		11.20	12.01	12.81	13.35	13.89	14.69	15.50
28	7	8.10	8.68	9.27	9.65	10.04	10.62	11.21
		10.80	11.58	12.36	12.87	13.39	14.17	14.94
29	7¼	7.82	8.38	8.94	9.32	9.69	10.26	10.82
		10.42	11.17	11.93	12.43	12.93	13.68	14.43
30	7½	7.55	8.10	8.64	9.00	9.37	9.91	10.45
		10.08	10.80	11.53	12.01	12.50	13.22	13.95
31	7¾	7.31	7.84	8.36	8.71	9.07	9.59	10.12
		9.75	10.46	11.16	11.63	12.10	12.80	13.50
32	8	7.08	7.59	8.10	8.44	8.78	9.29	9.80
		9.44	10.12	10.80	11.25	11.70	12.38	13.06
33	8¼	6.86	7.36	7.85	8.18	8.51	9.01	9.50
		9.15	9.81	10.47	10.91	11.35	12.01	12.66
34	8½	6.66	7.14	7.62	7.94	8.26	8.74	9.22
		8.88	9.52	10.16	10.58	11.01	11.65	12.29
35	8¾	6.46	6.93	7.40	7.71	8.02	8.48	8.95
		8.62	9.24	9.86	10.27	10.6	11.31	11.93

TALKING MOVIES

CARRYING CAPACITY OF COPPER WIRE

B. & S. Gauge	Circular Mils	Table A Rubber Insulat. Ampere	Table B Other Insulats. Ampere
18	1,624	3	5
16	2,583	6	8
14	4,107	15	16
12	6,530	17	23
10	10,380	24	32
8	16,510	35	46
6	26,250	50	65
5	33,100	54	77
4	41,740	65	92
3	52,630	76	110
2	66,370	90	131
1	83,690	107	156
0	105,500	127	185
00	133,100	150	200
000	167,800	177	262
0000	211,600	210	312
	200,000	200	300
	300,000	270	400
	400,000	330	500
	500,000	390	590
	600,000	450	680
	700,000	500	760
	800,000	550	840
	900,000	600	920
	1,000,000	650	1,000
	1,100,000	690	1,070
	1,200,000	730	1,150
	1,300,000	770	1,220
	1,400,000	810	1,290
	1,500,000	850	1,360
	1,600,000	890	1,430
	1,700,000	930	1,490
	1,800,000	970	1,550
	1,900,000	1,010	1,610
	2,000,000	1,050	1,670

The lower limit is specified for rubber-covered wires to prevent gradual deterioration of the high insulations by the heat of the wires, but not from fear of igniting the insulation. The question of drop is not taken into consideration in the above tables.

TALKING MOVIES

USEFUL EQUIVALENTS FOR ELECTRIC HEATING PROBLEMS

Unit.	Equivalent Value In Other Units.	Unit.	Equivalent Value In Other Units.
1 K. W. Hour =	1,000 Watt hours 1.34 horse power hours 2,654,200 ft. lbs. 3,600,000 joules 3,412 heat units 367,000 kilogram metres .229 lbs. coal oxidized with perfect efficiency 3.53 lbs. water evaporated at 212° F. 22.75 lbs. of water raised from 62° to 212° F.	1 ft. lb. =	1.356 joules .1383 k. g. m. .000000377 K. W. hour .0001285 heat units .0000005 H. P. hour
1 H. P. Hour =	.746 K. W. hour 1,930,000 ft. lbs. 2,545 heat units 273,740 k. g. m. .175 lbs. coal oxidized with perfect efficiency 2.64 lbs. water evaporated at 212° F. 17.0 lbs. water raised from 62° F. to 212° F.	1 Watt =	1 joule per second .00134 H. P. .001 K. W. 3,412 heat units per hour .7373 ft. lbs. per second .003 lbs. of water evaporated, per hour 44.24 ft. lbs. per minute
1 K. W. =	1,000 Watts 1.34 H. P. 2,654,200 ft. lbs. per hour 44.24 ft. lbs. per minute 737.3 ft. lbs. per second 3,412 heat units per hour 36.9 heat units per minute 9.48 heat units per second .2275 lbs. coal oxidized per hour 2.58 lbs. water evaporated per hour at 212° F.	1 Watt per Sq. in. =	8.19 thermal units per sq. ft. per minute 120° F. above surrounding air (Japanned cast iron surface) 66° C. above surrounding air (Japanned cast iron surface)
1 H. P. =	.746 Watts .746 K. W. 33,000 ft. lbs. per minute 550 ft. lbs. per second 2,545 heat units per hour 42.4 heat units per minute .707 heat units per second .175 lbs. coal oxidized per hour 2.64 lbs. water evaporated per hour at 212° F.	1 Heat Unit =	1055 Watt seconds 778 ft. lbs. .252 calorie (Kg. d.) 107.6 kilogram metres .000293 K. W. hour .000393 H. P. Hour .0000688 lbs. coal oxidized .001036 lbs. water evaporated at 212° F.
1 Joule =	1 Watt second .00000278 K. W. hour .102 k. g. m. .0009477 heat units .7373 ft. lbs.	1 Heat Unit per Sq. Ft. per Minute =	1221 Watts per sq. inch .0176 K. W. .0296 H. P.
		1 Kilogram Metre =	7.2314 ft. lbs. .00000366 H. P. hour .00000272 K. W. hour .0093 heat units
		1 lb. Bituminous Coal Oxidized with perfect efficiency =	14,544 heat units 1.11 lbs. Anthracite coal oxidized 2.5 lbs. dry wood oxidized 21 cu. ft. illuminating gas 4.26 K. W. hours (theoretical value) 5.71 H. P. hours (theoretical value) 11,315,000 ft. lbs. (theoretical value) 15 lbs. of water evaporated at 212° F.
		1 lb. Water Evaporated at 212° F. =	.283 K. W. hour .379 H. P. hour 965.7 heat units 103,900 k. g. m. 1,019,000 joules 751,300 ft. lbs. 66.4 lbs. of coal oxidized

TALKING MOVIES

EQUIVALENTS OF UNITS OF LENGTH

	Milli-meter	Centi-meter	Meter	Kilo-meter	Mil	Inch	Foot	Yard	Mile (Stat.)	Mile (Geog.)
Millimeter	1	01	.001	.000001	39,370.79	.039371	.003281	.001094	.0000006	.0000097
Centimeter10	1	1	.00001	393.7079	.3937079	.032809	.010936	.0000062	.000007
Meter	1000	100	1	.001	39,370.79	39.37079	3.28090	1.09363	.000621	.000716
Kilometer	1,000,000	100,000	1000	1		39,370.79	3280.899	1093.633	.621382	.716330
Mi025309	.0025399	.0000254		1	.001	.000083	.000028		
Inch	25.3994	2.53994	.025399	.0000254	1000	1	.083333	.027777	.0000158	.000015
Foot	304.7945	30.47945	.304795	.0003084	12000	12	1	.333333	.000189	.000104
Yard	914.3835	91.43835	.914384	.0000144	36000	36	3	1	.000608	.000493
Mile (Statute) ...		160,931.4	1,609.314	1,609,314		63,360	5280	1760	1	.868381
Mile (Geog'ph.) .		185,329	1853.29	1,853,290		72,063.2	6080.27	2026.76	1.1516	1

TALKING MOVIES

VOLTS LOST ON COPPER WIRE

Table of volts lost or drop per ampère per 1,000 feet of conductor. (Calculated by $E = I \times R$. Formula (29).) Copper wire, B. & S. gauge (70° F.).

Size, B. & S.	Volts Drop per Ampère per 1,000 Ft.	Size, B. & S.	Volts Drop per Ampère per 1,000 Ft.
0000	.0493	17	5.088
000	.0621	18	6.415
00	.0783	19	8.089
0	.0987	20	10.20
1	.1242	21	12.86
2	.1570	22	16.22
3	.1980	23	20.45
4	.2496	24	25.79
5	.3148	25	32.52
6	.3970	26	41.01
7	.5006	27	51.72
8	.6312	28	65.21
9	.7953	29	82.23
10	1.040	30	103.7
11	1.266	31	130.7
12	1.696	32	164.9
13	2.012	33	207.9
14	2.537	34	262.2
15	3.200	35	330.6
16	4.035	36	416.8

TALKING MOVIES

CONVERSION TABLES

(1) WATTS TO HORSE POWER

Watts	Horse Power	Kilowatts	Horse Power
1	.0014	.5	.670
5	.0067	.75	1.005
10	.0134	1.0	1.34
20	.0268	2.0	2.68
25	.0335	3.0	4.02
30	.0402	4.0	5.36
40	.0536	5.0	6.70
50	.067	6.0	8.04
75	.100	7.0	9.38
100	.134	8.0	10.0
200	.268	9.0	12.1
250	.335	10.0	13.4

(2) HORSE POWER TO WATTS

Horse Power	Watts	Horse Power	Kilowatts
$\frac{1}{8}$	46.62	4	2.984
$\frac{1}{8}$	93.25	5	3.730
$\frac{1}{4}$	186.5	6	4.476
$\frac{1}{2}$	373.0	7	5.222
$\frac{3}{4}$	559.5	8	5.968
1	746.0	9	6.714
2	1492.0	10	7.460
3	2338.0	20	14.920

TALKING MOVIES

POWER REQUIRED FOR DRIVING FANS

Diameter of Blades	Power required in Watts	Approx. cub. feet of Air moved per hour	Average Speed in Revolutions per minute
12 inches	50	60,000	1,000
15 "	70	72,000	900
18 "	100	120,000	750
24 "	200	300,000	600
30 "	350	420,000	500
36 "	450	720,000	450
42 "	550	840,000	360
48 "	650	1,000,000	300

SPARKING DISTANCES IN AIR

Volts	Distance (Inches)	Volts	Distance (Inches)
5,000	.225	60,000	4.65
10,000	.47	70,000	5.85
20,000	1.00	80,000	7.1
30,000	1.625	100,000	9.6
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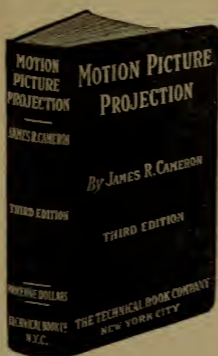
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